

INSTRUCTION MANUAL

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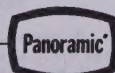
GERTSCH

PHASE ANGLE VOLTMETER
(PAV-4 SERIES)

3/69

SINGER
INSTRUMENTATION

Precision electrical and electronic instruments for measurement



THE SINGER COMPANY • METRICS DIVISION

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REPAIR AND MAINTENANCE

Instruments should be returned only on prior written authorization from the Singer Representative or the factory⁽¹⁾. Warranty repair will be made upon written request. Please provide the following information in order to expedite our processing of your instrument:

- | | |
|--|--|
| 1. Model or Type | 5. Approximate date instrument was placed in operation |
| 2. Serial Number | 6. Approximate number of hours of use |
| 3. Description of trouble ⁽²⁾ | 7. Has maintenance action been previously requested? |
| 4. Test instruments used | 8. Other comments |

Upon receipt of this information our Service Department will send you service data or shipping instructions. Upon receipt of shipping instructions forward the instrument to the factory prepaid. If requested, an estimate of charges will be made before work begins.

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Contact Metrics Division, 3211 S. LaCienega Blvd., Los Angeles, California for *Gertsch* instruments.
Contact Metrics Division, 7338 Varna Ave., N. Hollywood, California for *EMC* instruments.

(2) Include data on symptoms, measurements taken, suspected location of trouble, maintenance action taken, and any other relevant data.

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FOREWORD

This instruction manual provides operation and maintenance data for the Gertsch Model PAV-4 Series Phase Angle Voltmeters. Sections I through VI cover the basic units, Models PAV-4A and PAV-4B. Sections VII and subsequent provide data on the various plug-in modules used with the basic unit.

The information refers to the standard model listed above and is current only to the date of publication. Differences

resulting from the Singer Company's continuous product improvement program are described in addendum sheets. Additional models reflecting customer design and application requirements are described in difference data sheets.

In some cases, part values, ratings and manufacture source are nominal and variations may be found. Satisfactory replacement may be made with either the listed component or an exact replacement of the part(s) removed from the equipment.

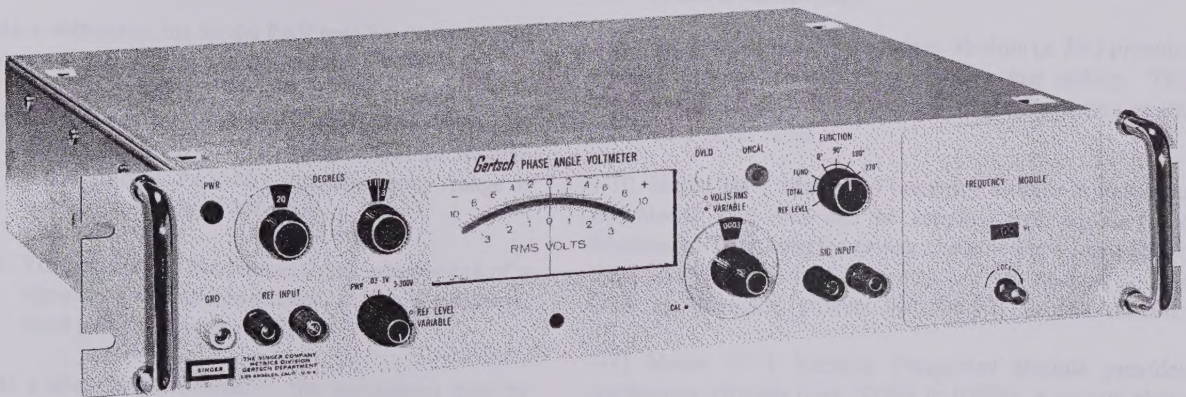


Figure 1-1. Model PAV-4 Phase Angle Voltmeter

SECTION I

GENERAL DESCRIPTION

1-1. PURPOSE

1-2. Model PAV-4 Phase Angle Voltmeter combines the capabilities of a standard voltmeter and a phase sensitive voltmeter into a single unit.

- a. In combination with Gertsch synchro and resolver test equipment, the Model PAV provides complete checkout capabilities for AC rotating components.
- b. In transfer function and filter analysis, the Model PAV provides gain and phase shift readouts on a single panel. Through the use of a variable range control, gain may be displayed as a direct percentage readout.
- c. The variable frequency modules use a unique heterodyne system in which the Model PAV is phase locked to an incoming signal. This capability allows the Model PAV-4 to be used for any application which requires pin-point analysis at a unique frequency.

1-3. As a voltmeter, the Model PAV may be used in either of two ways:

- a. To measure the total rms voltage of any AC signal in the 30Hz to 300KHz range. With an isolated input (Model PAV-4B), the frequency range is limited to 300Hz to 300KHz.
- b. To measure the fundamental rms component of a signal at a selected frequency. In this application, band pass filtering is provided.

1-4. As a phase angle voltmeter, the instrument may be used for a variety of tests in three basic ways:

- a. To measure the phase angle between a signal and reference voltage (phase shift through a test piece or system). The Model PAV may be used to measure amplitude at this phase shift angle.
- b. To measure the in-phase and quadrature components of the input signal.
- c. As a phase sensitive null indicator for extremely accurate bridging circuits. A high tolerance to a quadrature component allows null measurements under a wide variety of conditions. This tolerance

is expressed as overload ratio; as noted in the specifications, the quadrature input may be ten times the full scale voltage of the selected range without disturbing the null measurement.

1-5. Front panel controls provide fast changes in mode of operation. In-phase, quadrature, fundamental, and total voltage comparisons may be made without changing the test set-up. The PAV may be switched from use as a sensitive null indicator to measuring absolute voltage magnitude, again without changing a test set-up.

1-6. MODEL DIFFERENCES.

1-7. Model PAV-4A features direct signal and reference inputs with maximum accuracy and the broadest frequency range in the total mode. Model PAV-4B features isolated inputs for measuring differential signals. With either mode, the input impedance is 10 megohms, 25pf, thus minimizing loading effects on a unit under test. (Add 45pf for rear terminals.)

1-8. PLUG-IN MODULES.

1-9. Model SF-1 Single Frequency Module ($\pm 5\%$) provides an economical approach to production line testing. This module can be supplied with any single frequency in the 30Hz to 10KHz range.

1-10. Model MF-1 Multiple Frequency Module is similar to the Model SF-1 but can be supplied with up to three frequencies. Operating frequency is selected by a front-panel, three-position switch. Frequency can be changed in the field by changing plug-in components in the module.

1-11. Model VF-1 Variable Frequency Module provides continuous coverage from 300Hz to 10KHz. A unique phase lock circuit eliminates precise tuning; a single tuning control is adjusted until a front panel light indicates phase lock. Remote tuning may also be used with this module.

1-12. Model VF-2 Variable Frequency Module provides continuous coverage from 10KHz to 300KHz. This module is similar to the Model VF-1.

1-13. DESCRIPTION

1-14. The Model PAV is a self-contained test instrument which only requires connection to a 115/230 vac power source. Power conversion is accomplished by selecting a switch setting and changing a fuse value.

TABLE I. SPECIFICATIONS

Voltage Range	300 μ vrms to 300 vrms in 13 ranges		Recorder Output	± 1 VDC or .3VDC, 1 MADC equals f.s. single-ended
Range Vernier	100% to 30% without affecting overload ratio		AC Amplifier Output	200MVRMS (approx) equals f.s. single-ended
Phase Range	-10 to 360 degrees, 0.1 resolution		Power	115/230V $\pm 10\%$, 50-400 Hz
Frequency Range			Size	3 $\frac{1}{2}$ "H x 19"W x 14"D
Total Mode, PAV-4A	30Hz to 300KHz		MODEL SF-1, MF-1	Plug-in Modules
Total Mode, PAV-4B	300Hz to 300 KHz		Frequency Range	30 Hz to 10 KHz
Filtered Mode	See Plug-in Module Specifications		Bandwidth	$\pm 5\%$
Accuracy			Phase Accuracy	0.5 degrees over entire frequency range.
Voltage, Total Mode	2% (50Hz to 20 KHz) of f.s. 3% (30Hz to 100 KHz) of f.s. 5% (100KHz to 300KHz) of f.s.		Phase T/C	0.004 degrees/degree C
Voltage, Filtered Modes	2% of f.s.		Harmonic Rejection	
Temperature Coefficient	$\pm 0.1\%/^{\circ}\text{C}$ from 25 $^{\circ}\text{C}$		Fund. Mode	45 db (3rd harmonic and above)
Input Impedance			PAV Mode	55 db
Signal	10M, 25 pf (nominal w/o rear term)*		MODEL VF-1, VF-2	Plug-in Modules
Reference	10M, 25 pf (nominal w/o rear term)*		Frequency Range	300 Hz to 10 KHz (VF-1) 10 KHz to 300 KHz (VF-2)
Input Common to Case			Bandwidth	Phase-locked to input reference
Grd, PAV-4B	200 pf (max w/o rear term)*		Phase Accuracy	(1.0 + 0.01f KHz) degrees
Reference Input Voltage	0.03V to 300 vrms		Phase T/C	0.03 degrees/degree C
Overload Ratio	10x Full Scale		Harmonic rejection	2nd > 40 db 3rd > 55 db
Noise	PAV-4A	PAV-4B		
Total Mode	20 μ V (max)	30 μ V (max)		
Fund. Mode	10 μ V (max)	15 μ V (max)		
Nulling Sensitivity	2 μ V	2 μ V		
Harmonic Rejection	See Plug-in Module Specifications			
Temperature Range	0 to 50 degrees C			

*Add 45 pf for rear terminals

1-15. All operating controls, indicators, and connectors are mounted on the front panel. Back panel connections include the following:

- a. A DC voltage or current output for driving a recorder or an external "go," "no-go" control system.
- b. An AC amplifier output.

NOTE

The amplitude of both the above outputs is directly related to the voltage indication.

- c. The remote tuning input for the variable frequency modules.

SECTION II

INSTALLATION

2-1. UNPACKING

2-2. No special handling or unpacking procedures are required. After unpacking, inspect unit for any evidence of damage.

2-3. MOUNTING

2-4. The unit is designed for standard 19" rack mounting however, mounting is not required and the unit may be used as a portable unit.

2-5. ELECTRICAL CONNECTIONS.

2-6. Determine voltage of power source (115 or 230 vac). Set slide switch A5S1 (located on the Power supply and regulator board) to appropriate position and select fuse F1 for power source (115 vac use 1/2 amp fuse, 230 vac use 1/4 amp fuse). The unit is set for 115 vac power when shipped from the factory, unless otherwise indicated.

2-7. INSTALLATION CHECKOUT

2-8. The calibration procedure included in Appendix B may be used as an acceptance test procedure.

SECTION III

OPERATING INSTRUCTIONS

3-1. PHASE ANGLE MEASUREMENT

- a. Check mechanical zero of meter. Reset if required.
- b. Connect reference input voltage to REF INPUT binding posts.
- c. Connect signal input (output of device under test) to SIG INPUT binding posts.
- d. Turn REF LEVEL switch cw from PWR position. The PWR indicator should light.
- e. Set FUNCTION switch to the REF LEVEL position.
- f. Adjust REF LEVEL and associated VARIABLE control as required to obtain a meter deflection to the REF LEVEL mark.
- g. Set FUNCTION switch and DEGREES controls to 0 degree.
- h. (1) If multiple frequency module is used, set FREQUENCY switch to the required frequency.
(2) If variable frequency module is used, adjust frequency control until lock indicator is lit. Approach from high frequency end.
- i. Adjust FUNCTION switch and DEGREES controls to obtain a maximum indication to the right on the meter. First set FUNCTION switch to the 0 degree position and then adjust DEGREES switch through its entire range. If the meter does not indicate a positive (to the right) peak deflection, turn FUNCTION switch to the 90 degree position and repeat adjustment of DEGREES switch. Adjust VOLTS-RMS (range) switch as required.
- j. Turn FUNCTION switch 90 degrees in either direction from the position at which maximum positive meter deflection was obtained.
- k. Adjust DEGREES controls to obtain an exact null on the meter. For more sensitive null indications, the VOLTS-RMS (range) switch may be turned to lower ranges until the OVLD lamp lights. When the light does light, use the next higher range. When an exact null is obtained, return the VOLTS-RMS range selector to original position.

1. With FUNCTION switch in the position (0, 90, 180, 270 degrees) which gives a meter deflection to the right (+), the phase angle between the signal and input reference voltages is equal to the angular position of the FUNCTION selector plus the dial indications of the 10 and 1 DEGREES controls. The total amplitude of the vector is indicated by the meter (if the VARIABLE range control is in the CAL position).

3-2. IN-PHASE AND QUADRATURE COMPONENT MEASUREMENTS.

- a. Adjust instrument as outlined in steps a through h of paragraph 3-1.
- b. Set VARIABLE control associated with VOLTS-RMS switch to the CAL position. Make certain the UNCAL indicator is not lit.
- c. To measure the in-phase component, turn the FUNCTION switch and DEGREES controls to the 0 degree position. The meter will then indicate the amplitude of the in-phase component.
- d. To measure the quadrature component, turn FUNCTION switch to the 90 degree position and DEGREES controls to the 0 degree position. The meter will then indicate the amplitude of the quadrature component.

NOTE

For more accurate measurement, the VOLTS-RMS (range) switch may be turned to lower ranges until the OVLD light lights. If the light does light, use the next higher range.

3-3. VARIABLE CONTROL USE. If a full scale meter reading, other than those available through use of the VOLTS-RMS (range) switch is desired, adjust the VARIABLE control as follows:

- a. Apply a signal with the required full scale amplitude to SIGNAL binding posts.
- b. Turn FUNCTION switch to the desired position.
- c. Starting with the highest range, turn VOLTS-RMS (range) switch to the first position which causes an off-scale meter indication.

- d. Adjust VARIABLE range control until the meter indicates full scale deflection. The UNCAL light will light when the VARIABLE range control is turned from the CAL position.

3-4. NULL INDICATOR USE. To use the instrument as a phase sensitive null indicator, proceed as follows:

- a. Adjust instrument as outlined in steps a through h of paragraph 3-1.
- b. Determine the phase angle of the axis along which a null is desired. This angle will be determined by the application.
- c. Set the sum of the FUNCTION selector and the DEGREES dials to equal the angle in step a above.
- d. Adjust the unit under test (or external test equipment) until the meter indicates zero voltage (null).
- e. To measure the quadrature voltage at null, turn FUNCTION switch 90 degrees from its initial setting in either direction.

NOTE

If an "error" signal is in-phase with the reference angle selected the deflection will be + and - if it is out-of-phase.

3-5. TOTAL VTVM OPERATION. To measure the total rms voltage of an incoming signal, proceed as follows:

- a. Check mechanical zero of meter. Reset if required.
- b. Turn REF LEVEL switch clockwise from the PWR position. The PWR indicator should light.
- c. Make certain that VARIABLE range control is in the CAL position.
- d. Connect input signal to SIG INPUT binding posts.
- e. Turn FUNCTION switch to TOTAL position.
- f. Turn VOLTS-RMS (range) switch to the lowest range which provides an on-scale reading.

3-6. FUNDAMENTAL VTVM OPERATION. To measure the fundamental rms component of an incoming signal (less noise and harmonics), proceed as follows:

- a. Check mechanical zero of meter. Reset if required.
- b. Turn REF LEVEL switch clockwise from the PWR position. The PWR indicator should light.
- c. Make certain that the VARIABLE range control is in the CAL position.
- d. Connect input signal to SIGNAL binding posts.
- e. If variable frequency module is used, adjust instrument as outlined in step a through h of paragraph 3-1.
- f. If multiple frequency module is used, turn FREQUENCY switch to the selected frequency.
- g. Turn FUNCTION switch to FUND position.
- h. Turn VOLTS-RMS (range) switch to the lowest range which provides an on-scale reading.

3-7. EXTERNAL CONNECTIONS.

3-8. VDC OUTPUT. To drive a recording device with a DC voltage, connect recorder between 1VDC (pin 4) and GRD (pin 3) terminals of the back panel terminal board. This output may be adjusted with the VARIABLE control (paragraph 3-3).

3-9. DC CURRENT OUTPUT. To drive a recording device or an external relay with DC current, remove jumper and connect device between 1MADC (pin 2) and GRD (pin 1) terminals of the back panel terminal board. This output may be adjusted with the VARIABLE control (paragraph 3-3). Replace jumper when device is disconnected.

3-10. VAC OUTPUT. To use the AC voltage output, connect device between AC out (pin 5) and GRD (pin 6) terminals of the back panel terminal board. This output may be adjusted with the VARIABLE control (paragraph 3-3).

3-11. EXTERNAL TUNING. To provide external tuning of the variable frequency, disconnect jumper between terminals 6 and 7 of the back panel terminal board. Connect a DC voltage source between EXT IN and GRD. For complete coverage the source should be continuously variable between approximately -5 to +5vdc. Adjust the voltage source instead of the front panel frequency control until the lock indicator is lit. The voltage source will take the place of the frequency control. Replace jumper when voltage source is removed.

TABLE 3-1. CONTROLS AND INDICATORS

PANEL MARKING	TYPE OF CONTROL (see figure 6-1)	FUNCTION
PWR	Indicator Light (DS)	ON-OFF power indicator.
DEGREES: 10° Steps 1 degree Markings (0.2° inc.)	Switch (S4) Potentiometer (R28)	Calibrated phase shifter. Adjusts the phase angle of the reference voltage as required to equal any phase angle within the set quadrant. The readings of these two dials plus the angular setting of the FUNCTION switch indicates the total phase angle FUNCTION = 90 degrees + DEGREES switch = 20 degrees + DEGREES potentiometer = 7 degrees Total phase angle = 117 degrees
RMS Volts	Meter (M1)	Zero center meter indicates rms voltage or nulls.
OVL D	Indicator light (DS2)	Lights to indicate that the total input signal voltage exceeds the selected range by a factor of 10.
UNCAL	Indicator light (DS3)	Lights to indicate that the VARIABLE range control has been rotated from the CALIBRATED position. Under these conditions, the meter does not indicate full scale voltages equal to the VOLTS-RMS switch settings.
FUNCTION	Rotary Switch (S3)	REF LEVEL — switches circuitry to meter and adjust reference input level.
		TOTAL — switches circuitry to measure total rms value of the input signal.
		FUND — switches circuitry to measure fundamental rms component of the signal.
		0, 90, 180, 270 Degrees — calibrated phase shifter used in conjunction with DEGREES controls. Adjusts phase angle of reference voltage for phase sensitive measurements.
SIG INPUT	Binding Posts (Red — HI) (J2) (Black — LO) (J3)	Input signal connection point.
VOLTS-RMS	Rotary Switch (S1)	13 position range control selects full-scale voltage range of instrument.
VARIABLE	Potentiometer (R5)	Adjustable attenuator provides a variable meter scale factor (an arbitrary input signal may be set for a full-scale meter indication, with the meter scale then used for direct percentage readouts).
REF LEVEL VARIABLE	Rotary Switch (S5) Potentiometer (R2-R3)	Adjusts reference channel to the amplitude level of the reference input. Also functions as power on-off control.
REF INPUT	Binding Posts (Red — HI) (J4) (Black — LO) (J5)	Reference input connection point.

TABLE 3-1. CONTROLS AND INDICATORS (CONT)

PANEL MARKING	TYPE OF CONTROL (see figure 6-1)	FUNCTION
GRD	Binding Post (J6)	Instrument case ground.
NOTE: The following connections are located on the back panel.		
1 MADC	Terminal Board (TB1)	Current output, analog of meter reading.
1 VDC		DC voltage output, 1 VDC for full scale.
DC Out		DC voltage output, analog of meter reading. i.e. 1V on 10's scales, .3V on 3 scales.
AC Out		AC voltage output, analog of input voltage.
VCO EXT In		Provides external tuning of the variable frequency modules.
LOCK IND.		Provides +12-14 VDC Out when VF-1/2 is locked.
SIGNAL INPUT (rear)	Binding Posts (Red – HI) (J8) (Black – LO) (J9)	Input signal connection point. These binding posts are not connected when low capacity input is desired.
REFERENCE INPUT (rear)	Binding Posts (Red – HI) (J10) (Black – LO) (J9)	Input reference voltage connection point. These binding posts are not connected when low capacity input is desired.
115/230V 50 - 400 Hz	Power cable (P1)	Power input.

SINGLE FREQUENCY MODULE

None		
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MULTIPLE FREQUENCY MODULE

Frequency	3-position rotary switch.	Select frequency for fundamental, or phase sensitive modes of operation.
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VARIABLE FREQUENCY MODULE

Frequency Dial	Potentiometer	Tunes module to operating frequency (fundamental and phase sensitive modes).
LOCK	Indicator Light	Lights to indicate that module is tuned to frequency.

3-12. NOTES ON OPERATION.

3-13. GROUND LOOPS. Ground loops should be avoided particularly when the unit is used as a phase sensitive voltmeter. To avoid ground loops (with PAV-4A), use isolation transformers (Gertsch Model ST103 and ST102 respectively, or equivalent) in the signal and reference input circuits.

3-14. BEAT NOTES. If the power and reference voltage have the same frequency, the two sources should be phase locked if the beat is objectionable to the operator. The most accurate reading is obtained by "averaging" the beat.

3-15. DETECTOR CIRCUIT. The VTVM detector circuit is an average responding circuit, calibrated to indicate rms value. When a square wave is applied (or a pulsating DC signal), the average-to-rms values change and therefore a correction factor must be applied to the meter reading:

- a. In the total mode, the meter reading is 1.11 times the peak value of the square wave input. A 100V peak-to-peak square wave will read 111 vrms.
- b. In the fundamental mode, the meter reading is 0.9 times the peak value of the square wave input. A 100V peak-to-peak square wave will read 90 vrms.

SECTION IV THEORY OF OPERATION

4-1. GENERAL THEORY

4-2. The signal circuitry, shown in the top section of the block diagram (figure 4-1) provides the range control circuitry and amplification for the signal input. The reference circuitry, shown in the bottom section of the block diagram, converts the reference input signal to the proper reference signal for the phase sensitive detector.

4-3. STANDARD VOLTMETER. When the instrument is used as a standard voltmeter, the reference circuitry is switched out and a full-wave rectifier is used as the meter detector. In the total function, the signal circuit is broad band and therefore the total incoming signal is applied to the meter circuit. The meter circuit is an average measuring circuit but the meter is calibrated to indicate rms value. In

the fundamental function, band pass filtering is switched into the signal circuit to minimize noise and harmonics. Under these conditions, the meter indicates the fundamental rms value of the incoming signal.

4-4. PHASE ANGLE VOLTMETER. When the instrument is used as a phase angle voltmeter, a phase sensitive bridge circuit is used as the meter detector. The reference circuit is switched into the system and supplies a reference signal with an adjustable phase angle to the bridge. The input and reference signals are compared in the phase sensitive bridge. When the phase angle of the detector reference signal is adjusted to exactly equal the phase angle of the input signal, the detector output is maximum. Since a filter is switched into the signal channel, the meter indicates the fundamental rms value of the signal input.

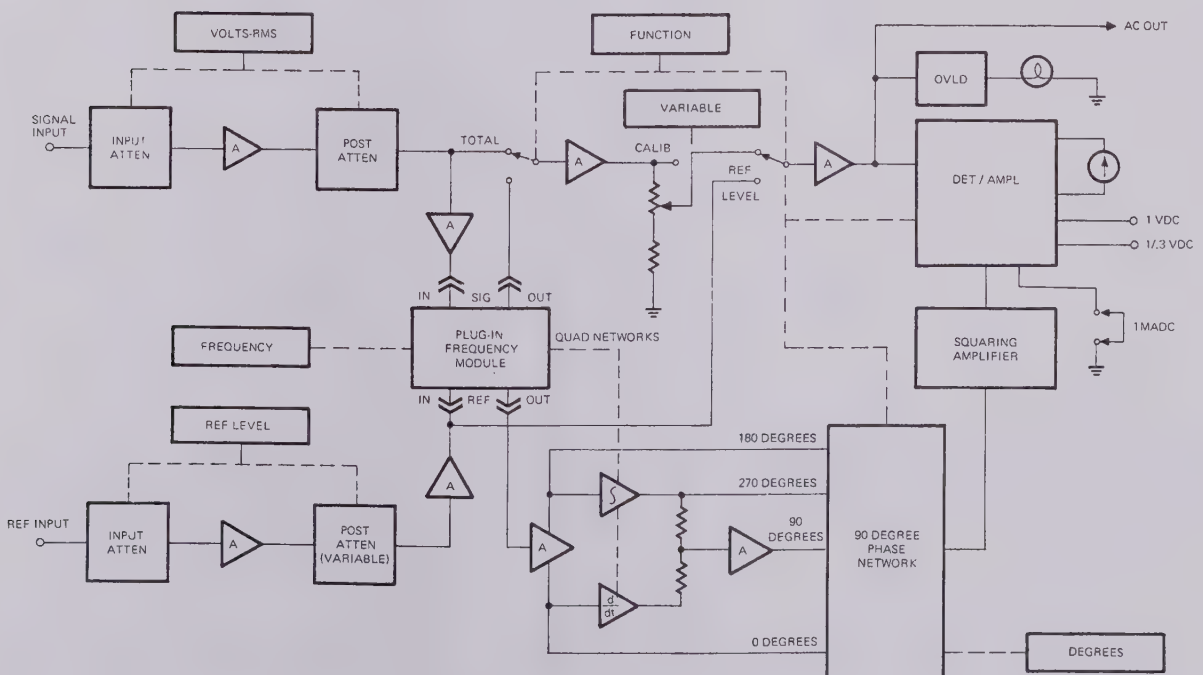


Figure 4-1. Block Diagram

4-5. If there is a phase shift through a unit under test, the output signal as related to the input signal contains two components: an in-phase component (X) and a quadrature component (jY). As shown in Figure 4-2, the phase angle is determined by the relative amplitudes of the components and by the arithmetical signs (plus or minus). At 45 degrees, the amplitudes are equal and both components have a plus sign. At 225 degrees, again the amplitudes are equal, but both components have a minus sign;

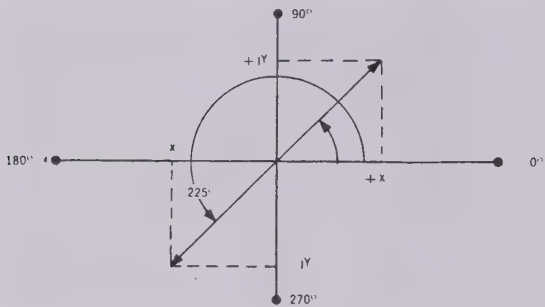


Figure 4-2. Input to Output Signal Relationships

4-6. The reference circuitry uses the reference input signal to generate the detector reference signal. The in-phase portion (X) is obtained by using the reference signal without change. The quadrature portion is obtained by shifting the phase of the reference voltage 90 degrees in a quadrature generator. The two components are combined in the phase angle network.

4-7. **PHASE ANGLE NETWORK.** A specific phase angle is selected by three controls: the function switch, the 10° DEGREES switch, and the interpolating potentiometer as shown in Figure 4-3. The function switch operates as the quadrant selector and places the proper in-phase and quadrature voltages across the 10 degree resistor network.

4-8. The degrees switch S4 positions the interpolating potentiometer within a resistor network. The network has an in-phase component applied to one end and a quadrature component applied to the other. At the midpoint of the network, the two components are equal. If both components have a plus sign, the midpoint equals a phase angle of 45 degrees. The resistance of the potentiometer provides a 10 degree span and may be placed within the network to provide coverage over any 10 degree span within the 90 degree quadrant.

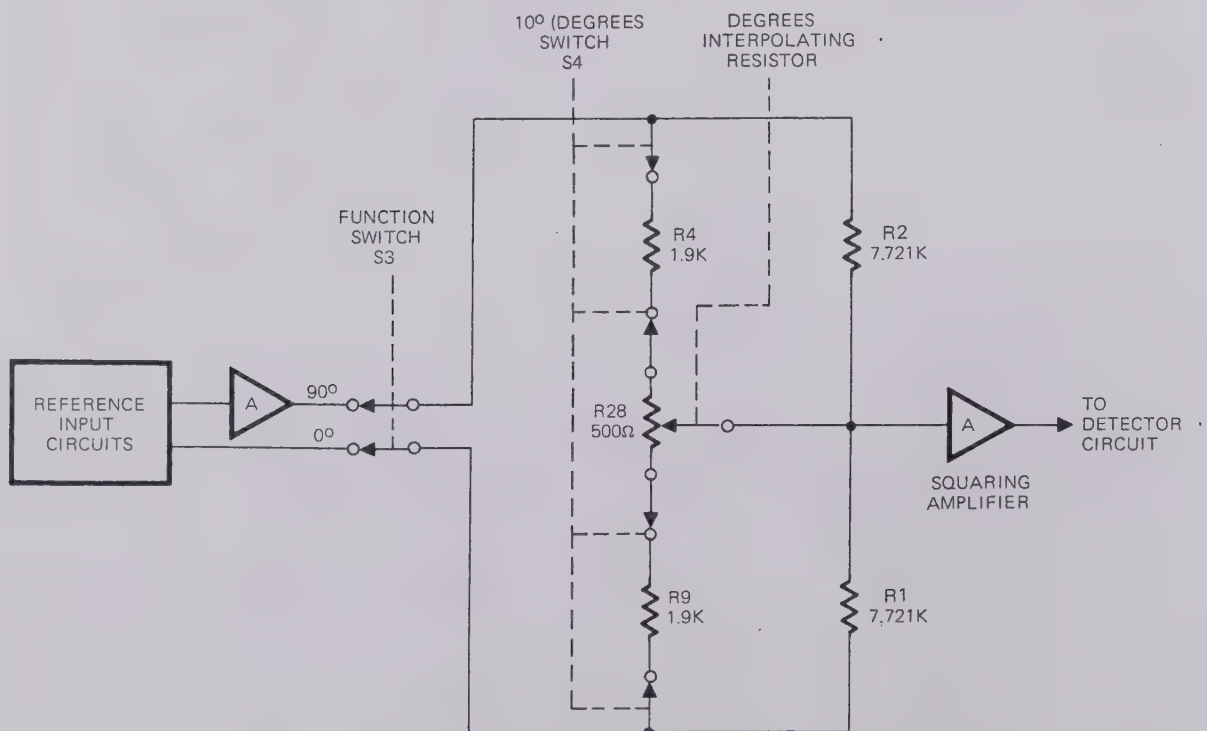


Figure 4-3. Phase Angle Network

4-9. FREQUENCY MODULES.

4-10. SINGLE FREQUENCY MODULE. This module provides a bandpass filter for the signal channel, a bandpass filter for the reference channel, and tuning components for the quadrature generators. These components provide fixed-frequency operation (see figure 4-4).

4-11. The components for the signal channel consist of a bandpass filter FL1, an emitter follower Q1, Q2, and a variable resistor R1 (FUND). This resistor compensates for variations in the insertion losses of the filters.

4-12. The components for the reference channel consist of a bandpass filter FL2 and the RC components for the two 90 degree generators. Phase resistor R5 compensates for minor phase shifts through the reference channel. Track resistor R3 adjusts the bandpass characteristics of the filter.

Resistor R10 adjusts the integrating amplifier and resistor R7 adjusts the differentiating amplifier.

4-13. MULTIPLE FREQUENCY MODULE. This module is similar to the single frequency module except that three sets of components are included.

4-14. VARIABLE FREQUENCY MODULE. This input signal and reference voltages are mixed with outputs of an oscillator to provide IF frequencies (see figure 4-5). The IF frequencies are then filtered and delivered to the PAV circuits.

4-15. The mixer frequency is provided by a DC voltage controlled oscillator. This oscillator is tuned by a variable potentiometer (frequency control) and the output of a phase detector. A highly stable, IF oscillator provides a comparison frequency for the phase detector. A second phase detector provides an output for the lock light.

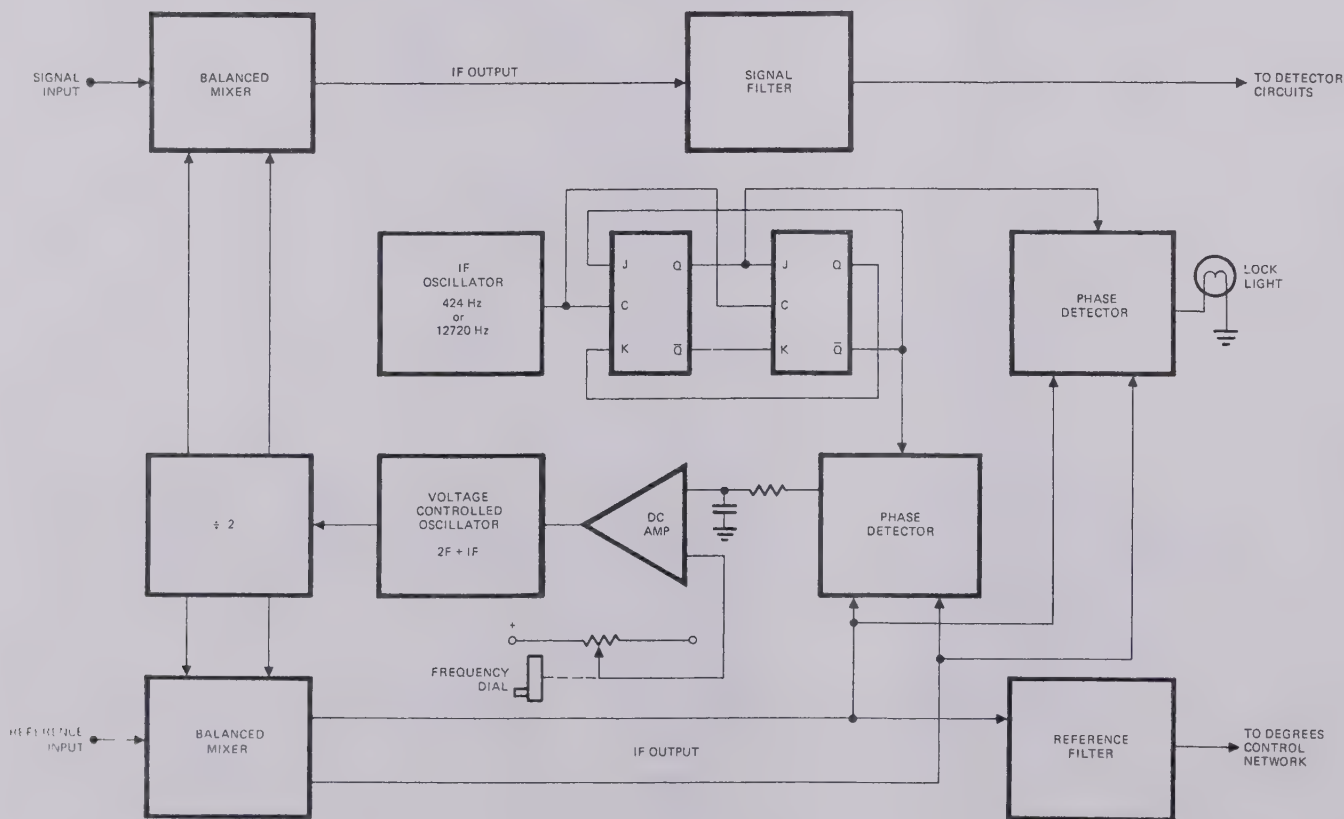
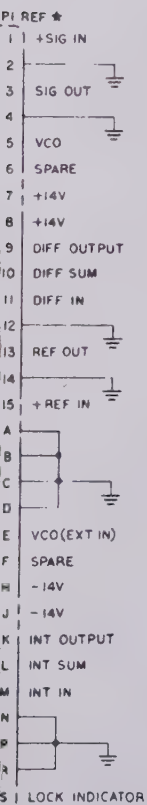
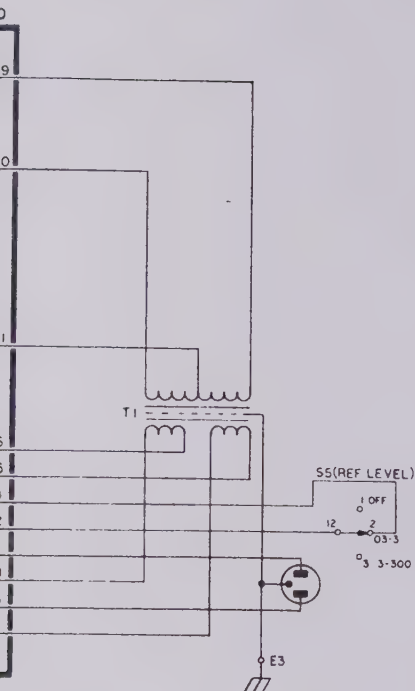


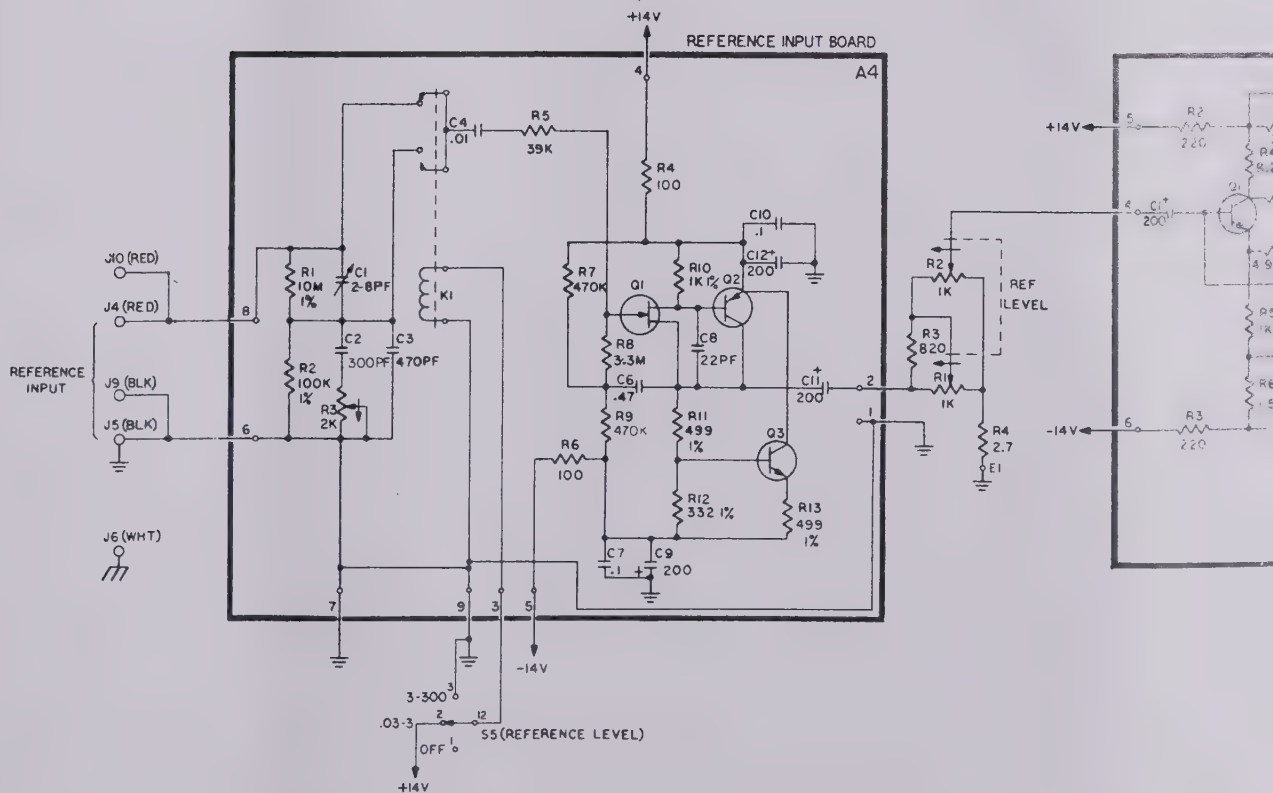
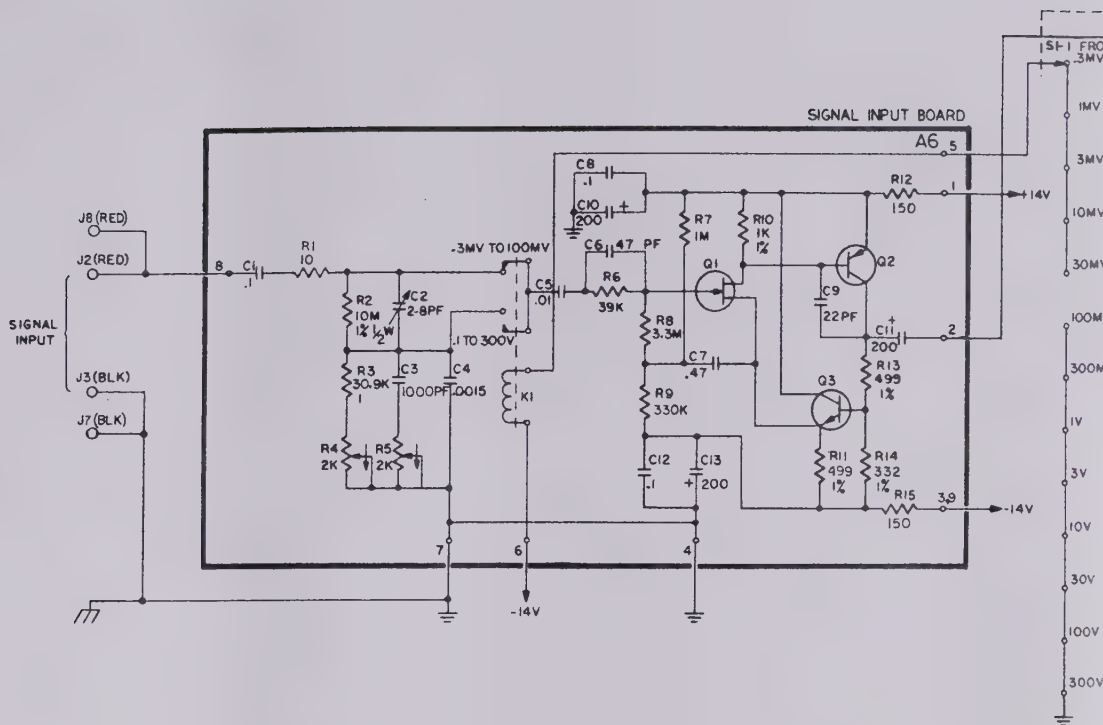
Figure 4-5. Variable Frequency Module

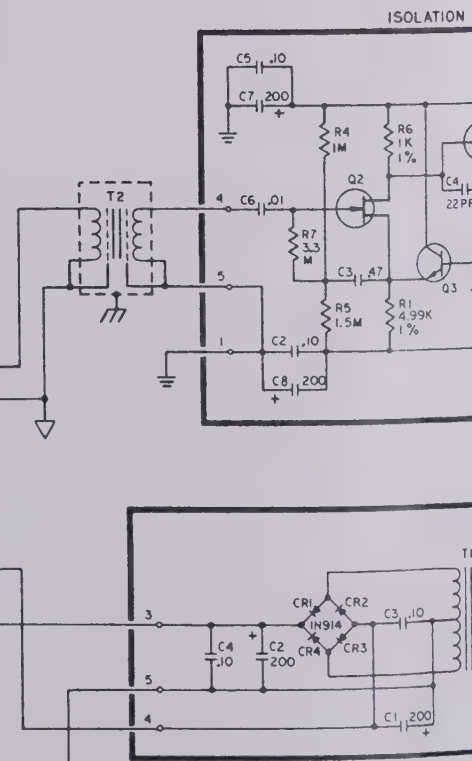
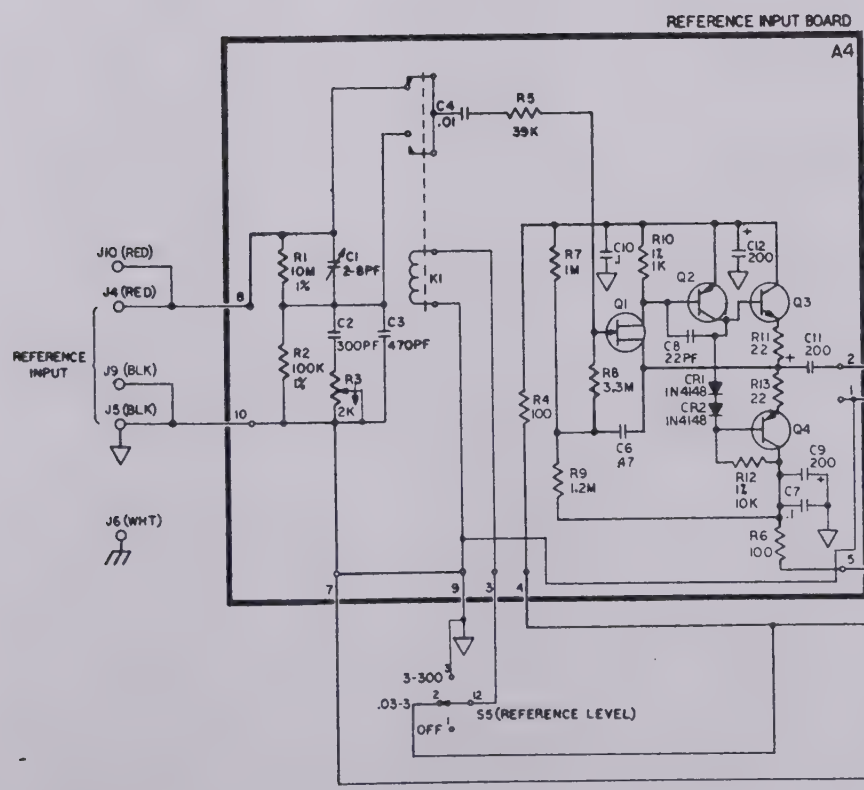
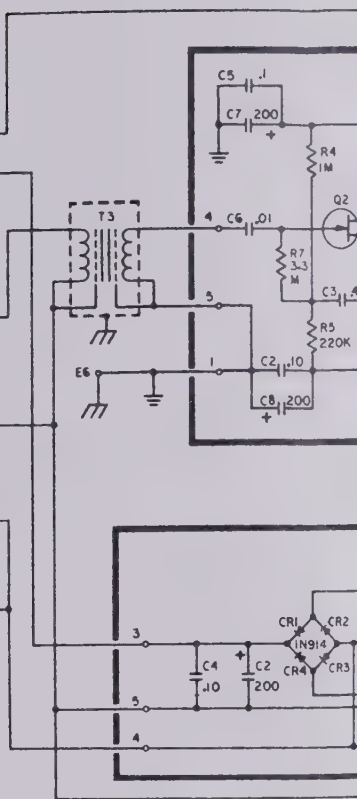
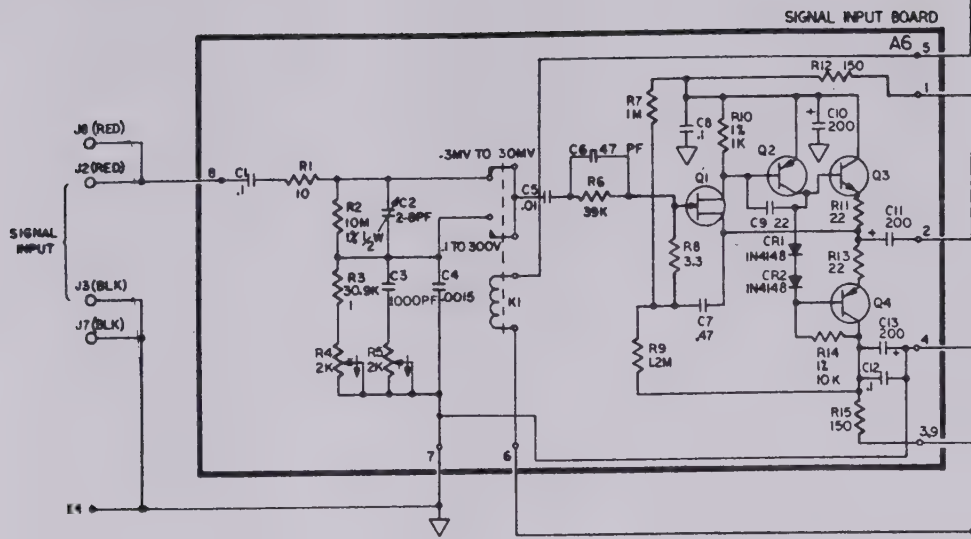


NOTES

1. RESISTOR VALUES IN OHMS, TOLERANCE $\pm 10\%$, $1/4W$ UNLESS OTHERWISE SPECIFIED.
2. CAPACITOR VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
3. COMPONENTS ON BOARD A1 DESIGNATED THUS * ARE TO BE SELECTED AT TEST.
4. ALL AREAS ENCLOSED BY A HEAVY LINE REPRESENT INDIVIDUAL CIRCUIT BOARD ASSEMBLIES. UNLESS OTHERWISE SPECIFIED ALL COMPONENTS OUTSIDE OF THESE AREAS ARE PART OF THE PAV TOP ASSEMBLY NO. 4-002712-001.
5. THE LAST REFERENCE DESIGNATOR USED ON BOARD:
 - A1— R13, S1
 - A2— AR3, C11, Q4, R26
 - A3— AR1, C4, Q6, R21
 - A4— C12, K1, Q3, R13 (5 OMITTED)
 - A5— C10, CR3, F1, Q6, R20, S1
 - A6— C13, K1, Q3, R15
 - A7— AR1, C14, R14
 - A8— AR4, C40, CR8, Q13, R77
 - A9— C10, Q3, R14 (R1 OMITTED)
6. COMPONENTS DESIGNATED * REPRESENT, IF EMPLOYED, THE COMPONENTS OF THE FREQUENCY MODULE ASSEMBLY.
7. LAST REFERENCE DESIGNATORS USED ON TOP ASSEMBLY:
 - A9, C2, O53, E1, J6, M1, Q2, R31, S5, T1, TBI
8. THE FUNCTIONS PER CONTACT NO. SHOWN ON S3-6 AND S3-12 ARE TYPICAL FOR ALL DECKS OF S3.
9. ARROWS THRU SWITCH AND POTENTIOMETER WIPERS INDICATE CW ROTATION.
10. THE FOLLOWING ARE FUNCTIONS FOR THE TOP ASSEMBLY SWITCHES:
 - S1 -- VOLTS RMS
 - S2 -- VARIABLE UNCAL
 - S3 -- FUNCTION
 - S4 -- PHASE SHIFT 10°
 - S5 -- REFERENCE LEVEL AND POWER

Figure 4-6. Schematic Diagram





SECTION V

MAINTENANCE

5-1. SCHEDULED MAINTENANCE.

5-2. The following schedule is recommended:

a. 90 Days.

- (1) Check adjustments as outlined in paragraphs 5-8 through 5-18.
- (2) Check for mechanical defects such as damaged components or insulation, loose hardware, etc.

b. Yearly.

- (1) Clean unit with vacuum cleaner.

5-3. No other scheduled maintenance is recommended.

5-4. UNSCHEDULED MAINTENANCE.

5-5. Refer to the schematic diagrams to trace troubles. Refer to Section VI for parts data.

5-6. TEST EQUIPMENT.

5-7. Refer to Table 5-1 for a list of test equipment.

NOTE

A test module equipped with the lowest and highest frequency may be substituted for the recommended module.

5-8. MAIN FRAME CALIBRATION ADJUSTMENTS.

5-9. PRELIMINARY ADJUSTMENTS. Proceed as follows:

- a. If any variable resistor on any of the circuit boards has been replaced or repaired, set resistor to approximately mid point.
- b. Check mechanical zero of meter. Reset if required.
- c. Connect to power source.
- d. Set front panel controls as follows:
 - (1) DEGREES switch to 0 degree.
 - (2) DEGREES vernier to 0 degree.
 - (3) REF LEVEL switch to .03 - 3V.
 - (4) VARIABLE REF LEVEL to mid point.
 - (5) VOLTS RMS to .0003.
 - (6) VARIABLE VOLTS RMS to CAL.
 - (7) FUNCTION switch to TOTAL.
- e. Check dc voltage between A5-18 and ground (A5-19). If required, adjust A5-R16 (see figure 6-6) to set voltage to +14 vdc.
- f. Check dc voltage between A5-20 and ground. If required, adjust A5-R19 to set voltage to -14vdc.
- g. Check dc voltage between collector A8-Q5 and ground. If required, adjust A8-R38 (see figure 6-9) to set voltage to 0 vdc.

TABLE 5-1. TEST EQUIPMENT

ITEM	MINIMUM USE SPECIFICATION	EQUIPMENT
Test Oscillator	50 Hz to 300 KHz	HP Model 651B.
Frequency Counter	50 Hz to 300 KHz	HP Model 5532A.
Voltage Divider	10 KHz, 5 decade range	Singer Model RT-63.
Differential Voltmeter		Fluke Model 931AB.
Differential Voltmeter		Fluke Model 883AB.
Test Module	400 Hz and 10 KHz	Singer Model MF-1.
Oscilloscope		HP Model 180A
Voltmeter		Simpson Model 269

- h. Check voltage between A3-11 and ground. If required, adjust A3-R19 (see figure 6-4) to set voltage to 0 vdc.
- i. Short SIG INPUT terminals. Meter should indicate less than +1 on the 0 to 10 scale.
- j. With a short jumper, ground A8-3. Meter should indicate less than ± 1 on the 0 to 10 scale.
- k. Adjust VM zero A8-R28 (see figure 6-9) to obtain zero indication on the meter.
- l. Remove jumper from A8-3 and short from SIG INPUT terminals.

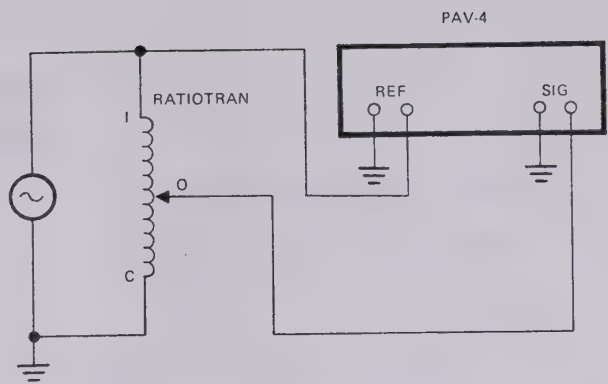


Figure 5-1. Test Setup

5-10. TOTAL VOLTMETER ADJUSTMENTS. With controls set as outlined in step l, paragraph 5-9, proceed as follows:

- a. Connect oscillator to SIG INPUT terminals and set output to 30 mv at 400 Hz.
 - b. Set VOLTS-RMS switch to .03.
 - c. Meter should indicate +3. Adjust TOT ADJ A7-R14 (see figure 6-8) as required to obtain indication.
 - d. Set oscillator output to 30mv at 300 KHz.
 - e. Meter should indicate +3. Adjust A8-C20 (see figure 6-9) as required to obtain indication.
 - f. Set oscillator output to 100mv at 100Hz (PAV-4A), or 300 Hz (PAV-4B). Set volts RMS to .1.
 - g. Meter should indicate +10. Adjust A6-R4 (see figure 6-7) as required to obtain meter indication.
 - h. Measure DC voltage between 4(+) and 3 (ground) on TB1. Adjust A8-R66 as required to obtain 1vdc output.
- d. Set oscillator output to 3V at 400 Hz.
 - e. Adjust VARIABLE control REF LEVEL as required to obtain a meter deflection to the REF LEVEL mark.
 - f. Set RatioTran to .001.
 - g. Set VOLTS-RMS switch to .003.
 - h. Set FUNCTION switch to total. Check that meter indicates $+3 \pm 2\%$.
 - i. Set RatioTran to .0011.
 - j. Set VOLTS-RMS switch to .0003.
 - k. Check that the OVLD indicator is out. If necessary, adjust A8-R6 (figure 6-9) until light goes out.
 - l. Set RatioTran to .0012. Check that OVLD indicator is lit. If necessary, adjust A8-R6 until light goes on.
 - m. Repeat steps i through l until indicator is lit with RatioTran set to .0012 and goes out with RatioTran set to .0011.

5-11. OVERLOAD ADJUSTMENT. Proceed as follows:

- a. Install the test frequency plug-in (Model MF-1 equipped for 400 Hz and 10 KHz). Set FREQUENCY switch to 400 Hz.
- b. Connect PAV into test setup shown in figure 5-1.
- c. Set front panel controls as follows:
 - (1) DEGREES switch to 0 degree.
 - (2) DEGREES vernier to 0 degree.
 - (3) REF LEVEL switch to .03 - 3V.
 - (4) VOLTS-RMS to .003.
 - (5) VARIABLE VOLTS-RMS to CAL.
 - (6) FUNCTION to REF LEVEL.

5-12. REFERENCE VOLTAGE ADJUSTMENT. With controls set as outlined in step m of paragraph 5-12, proceed as follows:

- a. Set RatioTran to .001.
- b. Set VOLTS-RMS to .003.
- c. Set FUNCTION to FUND.
- d. Adjust FUND resistor R1 on the frequency plug-in (400 Hz network) until meter indicates +3.
- e. Set FUNCTION to 0 degree.
- f. Measure voltage at A3-11 (180 degrees reference) and A3-12 (0 degrees reference) with rms differential voltmeter.

- g. Adjust A3-R15 (figure 4-1) until voltage at A3-12 (180 degrees reference) equals voltage at A3-11 (0 degree reference).
- h. Adjust integrating amplifier resistor R10 on the frequency plug-in (400 Hz network) until voltage at A2-22 (270 degrees reference) equals the voltage at A3-11 and A3-12.
- i. Adjust differentiating amplifier resistor R7 on the frequency plug-in (400 Hz network) until voltage at A2-15 (270 degrees reference) equals the voltage at A3-11 and A3-12.
- j. Adjust A2-R18 until voltage at A2-11 (90 degrees reference) equals the voltage at A3-11 and A3-12.
- k. Remove reference filter of frequency plug-in and replace with a jumper (pins 5 and 7).
- l. Vary oscillator frequency $\pm 5\%$ (from 380 to 420 Hz) while measuring voltage at A2-11. If voltage deviation exceeds 0.15%, adjust A2-R10 for minimum voltage deviation.
- m. Remove jumper (pins 5 and 7) and replace reference filter.
- n. Set FUNCTION to 90 degrees.
- o. Set VOLTS-RMS to 0.0003.
- p. Adjust phasing resistor R5 of module for a 0 volt indication.
- q. Vary oscillator frequency $\pm 5\%$ (from 380 to 420 Hz) and check meter indication. If meter exceeds ± 10 microvolts, adjust tracking resistor R3 of plug-in for minimum deviation.
- r. Adjust A8-R59 for 0 volts at A8-7.
- s. Remove signal and short signal input terminals.
- t. Adjust A8-R65 for zero on meter.
- u. Set oscillator to 10 KHz and repeat procedures of steps a through q, omitting steps k, l, and m.

5-13. PHASING ADJUSTMENTS. With controls set as outlined in step p, paragraph 5-12, proceed as follows (0 degree, 400 Hz):

- a. Set FUNCTION to 90 degrees.
- b. Set VOLTS-RMS to 0.0003.
- c. Adjust phasing resistor R5 on the frequency plug-in (400 Hz network) to obtain a zero indication on the meter.
- d. Set VOLTS-RMS to .3V.
- e. Set RatioTran to 1.000.

- f. Make certain REF LEVEL switch is in the .03 to 3V position.
- g. Adjust A6-C2 to obtain a zero indication on the meter.
- h. Set FUNCTION to REF LEVEL.
- i. Set REF LEVEL switch to 3 - 300V.
- j. Adjust VARIABLE control (REF LEVEL) as required to obtain a meter deflection to the REF LEVEL mark.
- k. Set FUNCTION to 90 degrees.
- l. Adjust A4-C1 as required to obtain a zero indication on the meter.
- m. Set oscillator output to 3V at 10 KHz.
- n. Set RatioTran to .001.
- o. Set FREQUENCY switch of plug-in to 10 KHz.
- p. Set front panel controls as follows:
 - (1) VOLTS-RMS to .0003.
 - (2) FUNCTION to REF LEVEL.
 - (3) REF LEVEL to .03 - 3V.
- q. Adjust VARIABLE control (REF LEVEL) as required to obtain a meter deflection to the REF LEVEL mark.
- r. Set FUNCTION to 90 degrees.
- s. Adjust phasing resistor R5 on the frequency plug-in (10 KHz network) to obtain a zero indication on the meter.
- t. Set VOLTS-RMS to .3V.
- u. Set RatioTran to 1.000.
- v. Adjust A6-R5 as required to obtain a zero indication on the meter.
- w. Set FUNCTION to REF LEVEL.
- x. Set REF LEVEL switch to 3 - 300V.
- y. Adjust VARIABLE control (REF LEVEL) as required to obtain a meter deflection to the REF LEVEL mark.
- z. Set FUNCTION to 90 degrees.
- aa. Adjust A4-R3 as required to obtain a zero indication on the meter.

5-14. PHASE SENSITIVE VOLTMETER ADJUSTMENTS.

- a. With test setup of paragraph 5-13, set front panel controls as follows:
 - (1) DEGREES switch to 0 degree.
 - (2) DEGREES vernier to 0 degree.
 - (3) REF LEVEL switch to .03 -3V.
 - (4) VOLTS-RMS to 1V.
 - (5) VARIABLE VOLTS-RMS to CAL.
 - (6) FUNCTION to REF LEVEL.
- b. Set oscillator output to 1V at 400 Hz.
- c. Set FREQUENCY switch of plug-in to 400 Hz.
- d. Set RatioTran to 1.000.
- e. Adjust VARIABLE control (REF LEVEL) as required to obtain a meter deflection to the REF LEVEL mark.
- f. Set FUNCTION to 0 degree.
- g. Adjust A8-R36 for a +1.0V indication on the meter.
- h. Measure DC voltage between 4(+) and 3 (ground) on TB1. Adjust A8-R65 as required to obtain 1vdc output.

5-15. PLUG-IN MODULE ADJUSTMENTS.

5-16. SINGLE FREQUENCY MODULE. Plug module into PAV and proceed as follows:

- a. Connect PAV into test setup shown in figure 5-1.
- b. Set oscillator for 3V output at the center frequency of the plug-in module.
- c. Set RatioTran to .001.
- d. Set front panel controls as follows:
 - (1) DEGREES switch to 0 degree.
 - (2) DEGREES resistor to 0 degree.
 - (3) REF LEVEL switch to .03 - 3V.
 - (4) VOLTS-RMS to .003.
 - (5) VARIABLE VOLTS-RMS to CAL.
 - (6) FUNCTION to REF LEVEL.
- e. Adjust VARIABLE (REF LEVEL) control as required to obtain a meter deflection to the REF LEVEL mark.
- f. Set FUNCTION to FUND.
- g. Adjust fundamental resistor R1 of the plug-in as required to obtain a 3 millivolt indication on the meter.

- h. Set FUNCTION switch to 0 degree.
- i. Measure voltage at A3-12 (0 degree reference).
- j. Measure voltage at A2-22. If necessary, adjust integrating amplifier resistor R10 of the plug-in to set integrator amplitude equal to 0 degree reference.
- k. Measure voltage at A2-15. If necessary, adjust differentiating amplifier resistor R7 of the plug-in to set differentiator amplitude equal to 0 degree reference.
- l. Set FUNCTION to 90° and volts RMS to .0003.
- m. Adjust phasing resistor R5 of the plug-in as required to obtain a zero indication on the meter.
- n. Vary oscillator frequency $\pm 5\%$ from center frequency and check meter indication. If meter exceeds 0.1 millivolt, adjust tracking resistor R3 of plug-in for minimum deviation. If R3 is changed, repeat step m.

5-17. MULTIPLE FREQUENCY MODULE. Repeat adjustments of paragraph 5-16 for each frequency of the module.

5-18. VARIABLE FREQUENCY MODULE.

- a. If any variable resistor has been replaced or repaired, set resistor to approximately mid point.
- b. If frequency dial circuit has been repaired (R35, R36, R37, R38, R86), preadjust circuit as follows:
 - (1) Connect ohmmeter between pins 2 and 3 of R86.
 - (2) Adjust potentiometer clockwise for a reading of approximately 10 ohms.
 - (3) Install dial with the lowest frequency on the dial aligned with the pointer.
 - (4) Turn REF LEVEL clockwise from the power off position.
 - (5) Connect voltmeter to the arm of the FREQUENCY resistor R86.
 - (6) Set R86 to the clockwise position and adjust R37 to obtain a voltmeter reading of -4.2 vdc.
 - (7) Set R86 to the counterclockwise position and adjust R35 to obtain a voltmeter reading of +4.5 vdc.
 - (8) Repeat steps (6) and (7) three times.

- c. Connect oscilloscope to TP1 and adjust R12 for a minimum square wave.
- d. Connect oscilloscope to TP2 and adjust R53 for a minimum square wave.
- e. Connect counter to TP3 and adjust R15 (on IF OSC board) for the following frequencies:
 - (1) 106.0 Hz for VF-1.
 - (2) 3180.0 Hz for VF-2.
- f. Apply a 30mv rms signal to the reference and signal inputs. Set to the following frequencies:
 - (1) 350 Hz for VF-1.
 - (2) 10 KHz for VF-2.
- g. Set FUNCTION switch to REF LEVEL.
- h. Adjust VARIABLE (REF LEVEL) control as required to obtain a meter deflection to the REF LEVEL mark.
- i. Set controls as follows:
 - (1) VOLTS-RMS to .03V.
 - (2) FUNCTION to FUND.
 - (3) DEGREES to 0°.
- j. Set R86 to the maximum frequency position. Adjust R68 until LOCK indicator just lights and then set R68 two turns clockwise. Check the LOCK indicator is off. Rotate R86 across its entire range and check the LOCK indicator remains off.
- k. Connect voltmeter to TP4. Set R86 to the minimum frequency position. Adjust R37 as required to obtain a LOCK indication. The voltmeter should indicate approximately -1V when lock occurs.
- l. Set R86 to the maximum frequency position and adjust test oscillator to the maximum frequency of the module. Adjust R36 as required to obtain a LOCK. The voltmeter (at TP4) should indicate approximately -1V when lock occurs.
- m. Repeat steps k and l until the FREQUENCY dial is aligned at both ends.
- n. Set R86 to the lowest frequency position and adjust test oscillator to the lowest frequency of the module. Set FUNCTION switch to 0°. Adjust R86 as required to obtain LOCK.
- o. Measure voltage at A3-11 (0 degree reference).
- p. Measure voltage at A2-22. If necessary, adjust integrating amplifier resistor R76 of the plug-in to set integrator amplitude equal to 0 degree reference.
- q. Measure voltage at A2-15. If necessary, adjust differentiating amplifier resistor R74 of the plug-in to set differentiator amplitude equal to 0 degree reference.
- r. Set FUNCTION to FUND.
- s. Adjust fundamental resistor R43 to obtain a 30 millivolt indication on the meter.
- t. Set FUNCTION to 90° and VOLTS-RMS to .003.
- u. Adjust phasing resistor R28 for a zero indication on the meter.
- v. Connect counter to TP3 and adjust R15 IF osc. board to obtain a + and - 0.5% variation in the IF frequency. Adjust R17 for a minimum deviation on the meter.
- w. Reset IF frequency to center frequency with R15.
- x. Adjust phasing resistor for a zero indication on the meter.
- y. Set R86 and the test oscillator to the highest frequency of the module and obtain a LOCK indication.
- z. Adjust capacitor C1 for a zero indication on the meter.

NOTE

The Model VF-1 is now calibrated. Proceed with steps aa and subsequent for the Model VF-2 only.

- aa. Set test oscillator to 3 volts at a frequency of 300 KHz.
- ab. Set REF LEVEL to .03-3V. Set FUNCTION to REF LEVEL. Adjust VARIABLE control to set meter to the REF LEVEL mark.
- ac. Set FUNCTION to 90°.
- ad. Adjust R86 to obtain a LOCK indication.
- ae. Set VOLTS-RMS to 0.3V.
- af. Adjust A6-R5 of main frame to obtain a zero indication on the meter.
- ag. Set REF LEVEL to 3-300V. Set FUNCTION to REF LEVEL. Adjust variable control to set meter to the REF LEVEL mark.
- ah. Adjust A4-R3 of main frame to obtain a zero indication on the meter.

SECTION VI

PARTS LIST

6-1. GENERAL.

6-2. This section lists and describes the electronic parts for the Model PAV-4A and PAV-4B main frames. The parts of the plug-in modules are listed in subsequent sections.

6-3. Many parts of the equipment are standard electronic

parts, procurable from a number of sources. Standard type designations are used to describe these parts and, in most cases, a primary manufacturer is listed.

6-4. Manufacturer codes used in this parts list are as procurable from a number of sources

VENDOR CODE

00327

01121

01295

02101

02660

03508

03614

04213

04387

04713

05574

11452

12406

15450

17856

58474

70903

VENDOR NAME AND ADDRESS

Welwyn International, Incorporated
Cleveland, Ohio

Allen Bradley
Milwaukee, Wisconsin

Texas Instruments, Incorporated
Dallas, Texas

Varo, Incorporated
Santa Barbara, California

Amphenol—Borg Electronics Corporation
Broadview, Chicago, Illinois

GECO
Semiconductor Products Division
Syracuse, New York

Bussman Fuse
Los Angeles, California

Caddel-Burns Mfg. Company, Incorporated
Mineola, New York

Dale Electronics, Incorporated
Burbank, California

Motorola, Incorporated
Phoenix, Arizona

Viking Industries, Incorporated
Canoga, Park, California

Jan Engineering
Santa Monica, California

Elpac. Incorporated
Fullerton, California

Erie Resistor Corporation
Erie, Pennsylvania

Siliconix, Incorporated
Sunnyvale, California

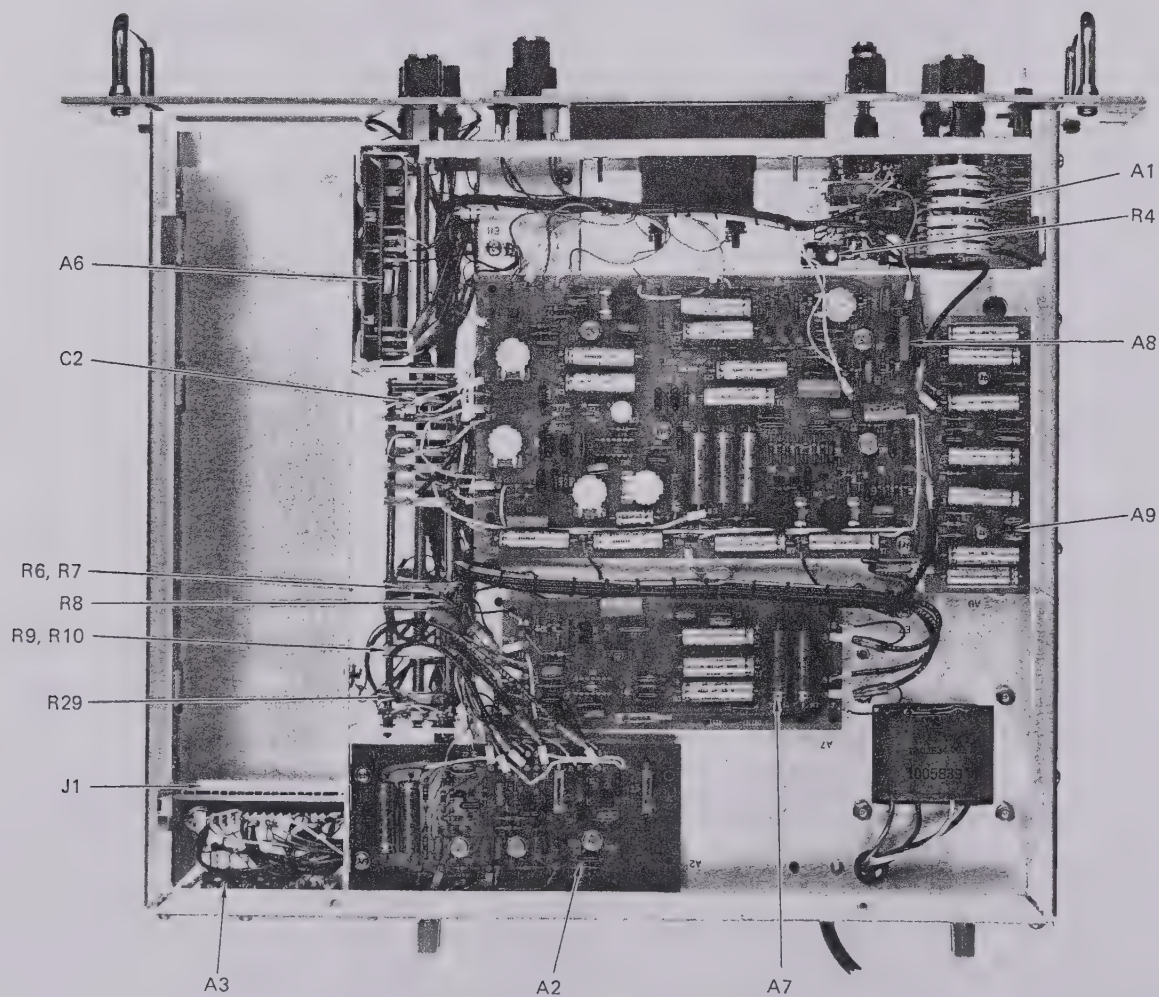
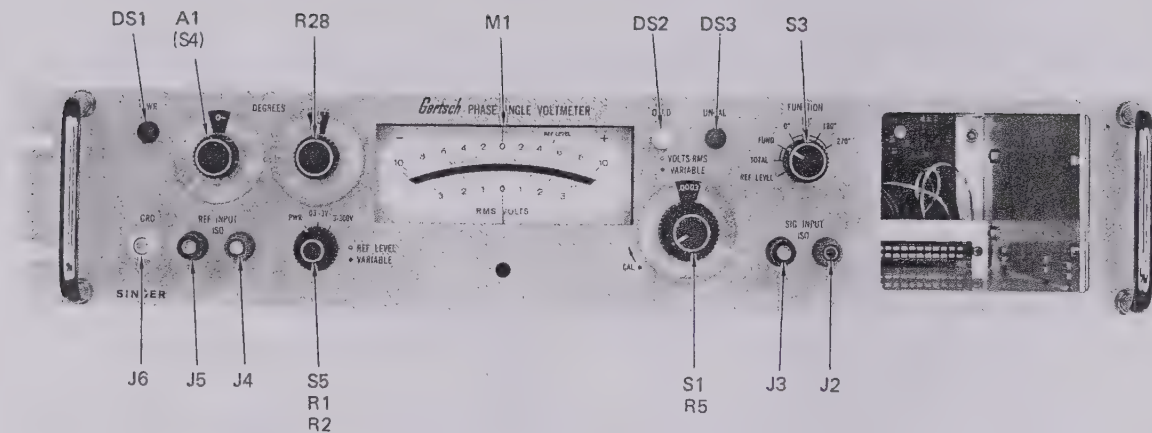
Superior Electric Company
Bristol, Connecticut

Belden Manufacturing Company
Chicago, Illinois

VENDOR CODE	VENDOR NAME AND ADDRESS
71450	CTS Corporation Elkhart, Indiana
71785	Cinch Manufacturing Company Chicago, Illinois
72136	Electro-Motive Manufacturing Company Williamantic, Connecticut
73445	Amperex Electronic Company Hicksville, New York
76433	General Instrument Corporation Capacitor Group Newark, New Jersey
79089	RCA Harrison, New Jersey
82389	Switchcraft, Incorporated Chicago, Illinois
X0001	Mura Corporation

**FIGURE 6-1.
PHASE ANGLE VOLTMETER**

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG. PART NO.	PAV-4A	PAV-4B
A1	10° Phase Shift Switch (see figure 6-2 for details)		88869	4-002787-001	A	B
A2	Quadrature Circuit Board (see figure 6-3 for details)		88869	5-002769-001	A	B
A3	Quadrature X5 Circuit Board (see figure 6-4 for details)		88869	4-002770-001	A	B
A4	Reference Input Circuit Board (see figure 6-5 for details)		88869	4-002700-001	A	
A4	Circuit Board, Reference Input (see figure 6-5 for details)		88869	4-002700-002		B
A5	Power supply Circuit Board (see figure 6-6 for details)		88869	5-002771-001	A	B
A6	Signal Input Circuit Board (see figure 6-7 for details)		88869	4-002699-001	A	
A6	Signal Input Circuit Board (see figure 6-7 for details)		88869	4-002699-002		B
A7	X1, X30 Circuit Board (see figure 6-8 for details)		88869	5-002767-001	A	B
A8	Detector Circuit Board (see figure 6-9 for details)		88869	5-002768-001	A	B
A9	Reference X5 Circuit Board (see figure 6-10 for details)		88869	4-002806-001	A	B
A10	Isolated Input Circuit Board (see figure 6-11 for details)		88869	4-002843-002		B
A11	Isolated Inverter Circuit Board (see figure 6-12 for details)		88869	4-002844-002		B
A12	Isolated Input Circuit Board (see figure 6-10 for details)		88869	4-002843-001		B
A13	Isolated Inverter Circuit Board (see figure 6-11 for details)		88869	4-002844-001		B
C1	Not Used					
C2	Capacitor, plastic, .1uf ±20%, 250vdc	1-900001-013	73445	Type C280AE	A	B
DS1	Light Indicator, Red	1-925007-003	X00001	L10/20	A	B
DS2	Light Indicator, White	1-925007-005	X00001	L10/20	A	B
DS3	Light Indicator, Amber	1-925007-001	X00001	L10/20	A	B
E1						



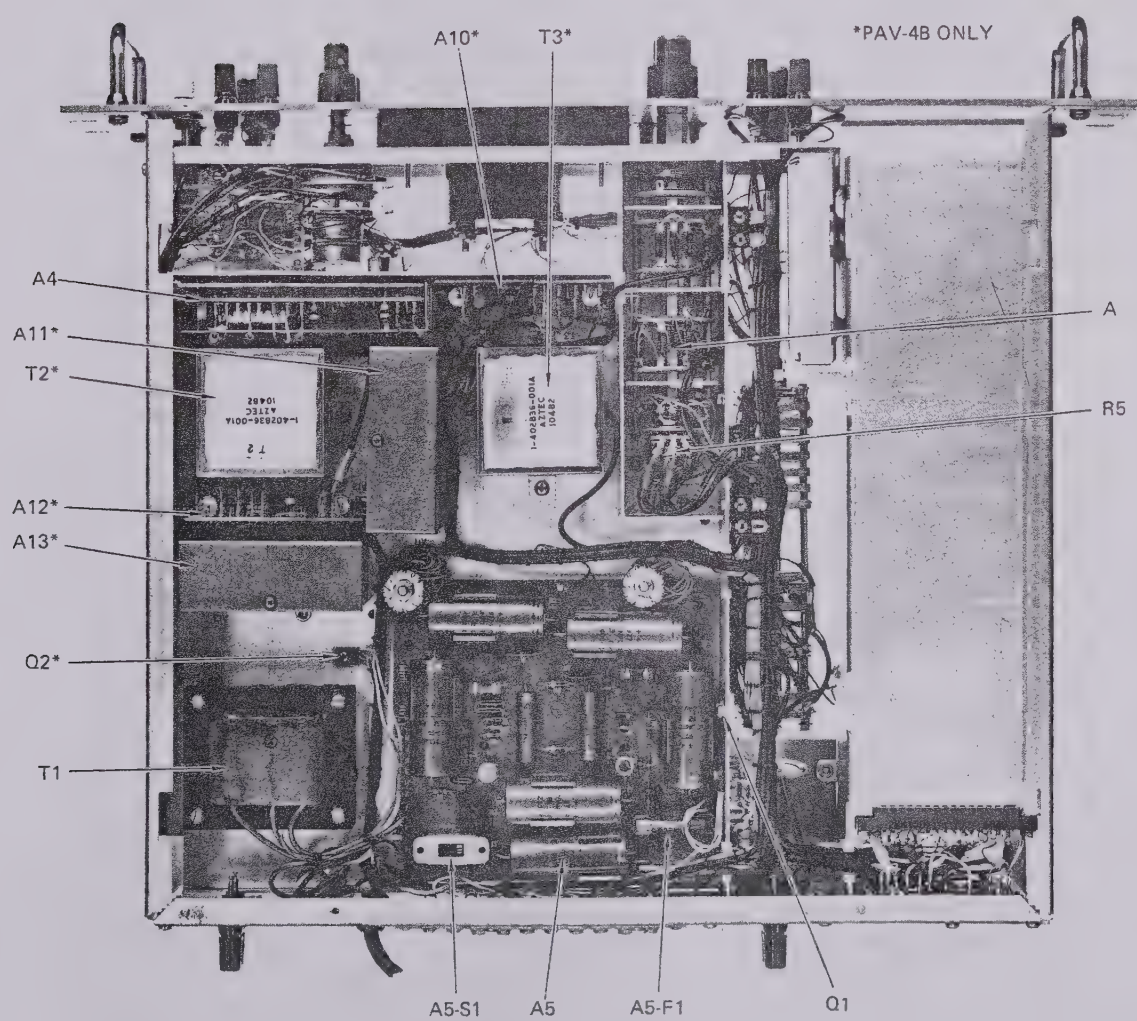
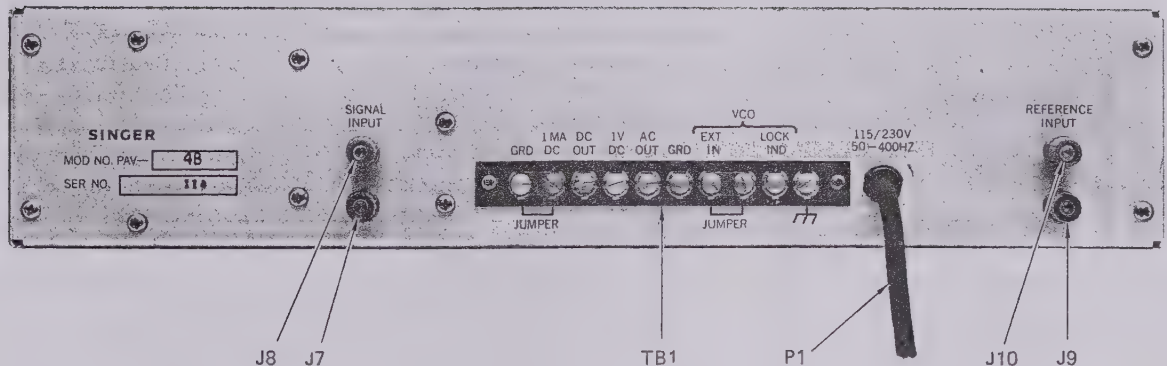


Figure 6-1. Phase Angle Voltmeter

REFDESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
E2	Stud, grounding	1-945145-001	11452	1001	A	B
E3						
E4	Link, Shorting	1-964140-001	71785	5 - 101	A	B
J1	Connector, Circuit Board	1-910082-003	05574	2UK15D1 - 1	A	B
J2	Binding Post, Red	1-941018-001	58474	DF21RC	A	B
J3	Binding Post, Black	1-941018-003	58474	DV21BC	A	B
J4	Binding Post, Red	1-941018-001	58474	DF21RC	A	B
J5	Binding Post, Black	1-941018-003	58474	DV21BC	A	B
J6	Binding Post, White	1-941018-002	58474	DF21WTC	A	B
J7	Binding Post, Black	1-941018-003	58474	DV21BC	A	B
J8	Binding Post, Red	1-941018-001	58474	DF21RC	A	B
J9	Binding Post, Black	1-941018-003	58474	DV21BC	A	B
J10	Binding Post, Red	1-941018-001	58474	DF21RC	A	B
M1	Meter, 1-0-1 ma		88869	3-402817-001	A	B
P1	Power Cord	1-910011-001	70903	17238B	A	B
Q1	Transistor, NPN	1-958001-002	04713	MJE520	A	B
Q2	Transistor, PNP	1-958001-001	04713	MJE370	A	B
R1	Resistor, variable, 1K $\pm 10\%$ (P/OS5)		88869	4-402819-099	A	B
R2	Resistor, variable, 1K $\pm 10\%$ (P/OS5)		88869	4-402819-099	A	B
R3	Resistor, comp, 820 ohms $\pm 10\%$, 1/4W	1-945000-036	01121	Type CB	A	B
R4	Resistor, comp, 2.7 ohms $\pm 10\%$, 1/4W	1-945000-006	01121	Type CB	A	B
R5	Resistor, variable, 1K $\pm 10\%$ (P/OS1)		88869	2-402868-001	A	B
R6	Resistor, film, 499 ohms $\pm 1\%$, 1/4W	1-945016-164		Type RN60D	A	B
R7	Resistor, film, 10K $\pm 1\%$, 1/4W	1-945016-289		Type RN60D	A	B
R8	Resistor, comp, 10K $\pm 10\%$, 1/4W	1-945000-049	01121	Type CB	A	B
R9	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB	A	B

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R10	Resistor, comp, 1K $\pm$ 10%, 1/4W	1-945000-037	01121	Type CB	A	B
R11	Resistor, film, 460.6 ohms $\pm$ 1/4%, 1/4W	1-945043-002	04387	Type MF1/8T1	A	B
R12	Resistor, film, 460.6 ohms $\pm$ 1/4%, 1/4W	1-945043-002	04387	Type MF1/8T1	A	B
R13	Resistor, film, 460.6 ohms $\pm$ 1/4%, 1/4W	1-945043-002	04387	Type MF1/8T1	A	B
R14	Resistor, film, 460.6 ohms $\pm$ 1/4%, 1/4W	1-945043-002	04387	Type MF1/8T1	A	B
R15	Resistor, film, 460.6 ohms $\pm$ 1/4%, 1/4W	1-945043-002	04387	Type MF1/8T1	A	B
R16	Resistor, film, 460.6 ohms $\pm$ 1/4%, 1/4W	1-945043-002	04387	Type MF1/8T1	A	B
R17	Resistor, film, 681 ohms $\pm$ 1/4%, 1/4W	1-945043-003	04387	Type MF1/8T1	A	B
R18	Resistor, film, 681 ohms $\pm$ 1/4%, 1/4W	1-945043-003	04387	Type MF1/8T1	A	B
R19	Resistor, film, 681 ohms $\pm$ 1/4%, 1/4W	1-945043-003	04387	Type MF1/8T1	A	B
R20	Resistor, film, 681 ohms $\pm$ 1/4%, 1/4W	1-945043-003	04387	Type MF1/8T1	A	B
R21	Resistor, film, 681 ohms $\pm$ 1/4%, 1/4W	1-945043-003	04387	Type MF1/8T1	A	B
R22	Resistor, film, 681 ohms $\pm$ 1/4%, 1/4W	1-945043-003	04387	Type MF1/8T1	A	B
R23	Resistor, comp, 220 ohms $\pm$ 10%, 1/4W	1-945000-029	01121	Type CB	A	B
R24	Resistor, comp, 22 ohms $\pm$ 10%, 1/4W	1-945000-017	01121	Type CB	A	B
R25	Resistor, film, 681 ohms $\pm$ 1/4%, 1/4W	1-945043-003	04387	Type MF1/8T1	A	B
R26	Resistor, film, 3149 ohms $\pm$ 1/4%, 1/4W	1-945043-001	04387	Type MF1/8T1	A	B
R27	Resistor, comp, 330 ohms $\pm$ 10%, 1/4W	1-945000-031	01121	Type CB	A	B
R28	Resistor, variable, 500 ohms $\pm$ 5%		88869	2-402855-001	A	B
R29	Resistor, comp, 2.7K $\pm$ 10%, 1/4W	1-945000-042	01121	Type CB	A	B
R30	Resistor, film, 681 ohms $\pm$ 1/4%, 1/4W	1-945043-003	04387	Type MF1/8T1	A	B
R31	Resistor, film, 3149 ohms $\pm$ 1/4%, 1/4W	1-945043-001	04387	Type MF1/8T1	A	B
S1	Switch, volts-RMS		88869	2-402868-001	A	B
S2	Switch, UNCAL (P/O R5)				A	B
S3	Switch, FUNCTION		88869	4-402822-099	A	B
S4	Switch, 10° Phase Shift (P/O A1)				A	B
S5	Switch, REF LEVEL		88869	4-402819-099	A	B
T1	Transformer, power		88869	1-402834-001	A	B

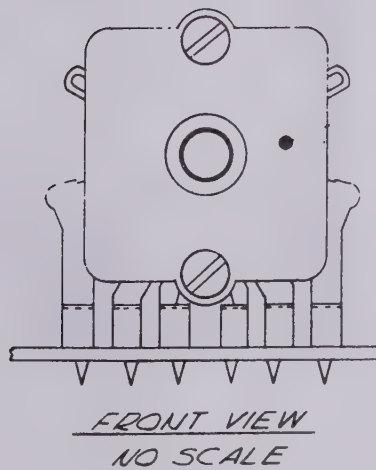
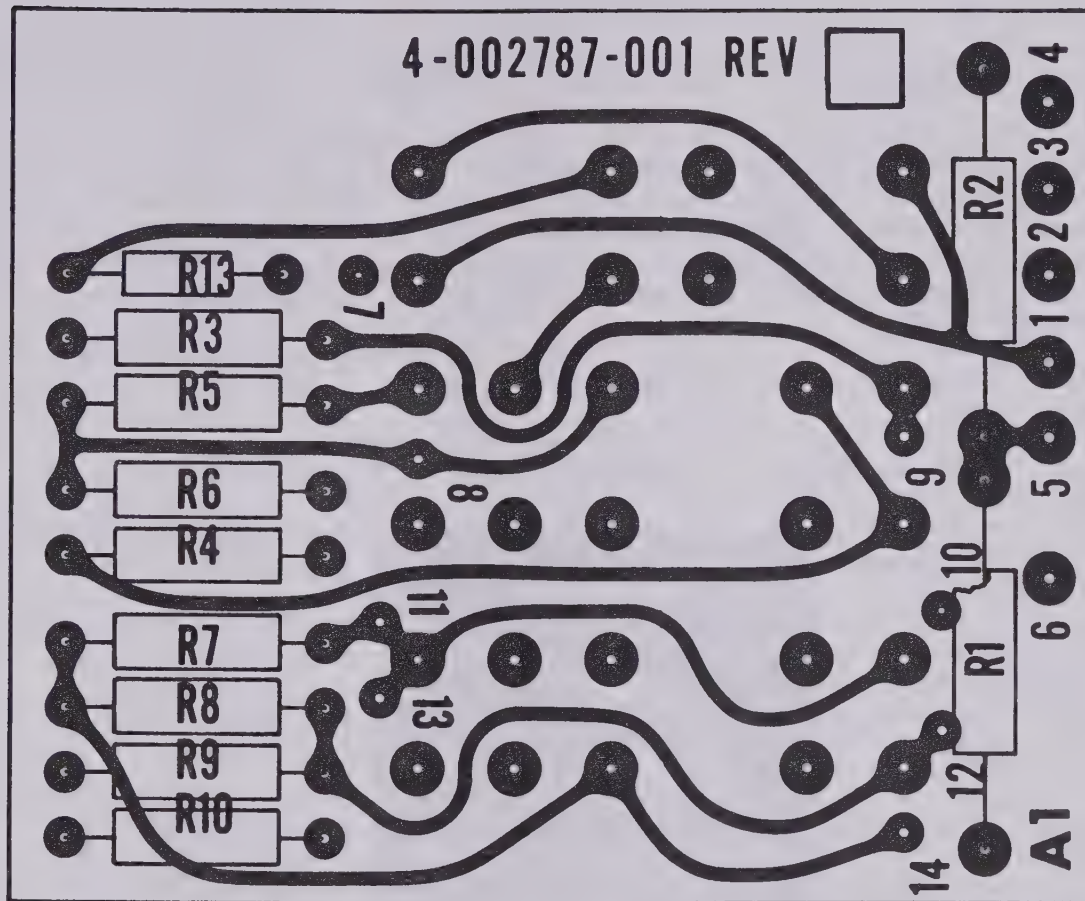


Figure 6-2. Switch Assembly – Phase Shift 10°

FIGURE 6-2.
10° PHASE SHIFT SWITCH A1

REF DESIG	DESCRIPTION	SINGER MFG NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R1	Resistor, film, 7.721K $\pm$ 1%, 1/4W	1-945016-581		Type RN60D		
R2	Resistor, film, 7.721K $\pm$ 1%, 1/4W	1-945016-581		Type RN60D		
R3	Resistor, ww, non-inductive, 475 ohms $\pm$ 0.05%, 1/8W	1-945040-001	04387	Type WWA13		
R4	Resistor, ww, non-inductive, 1.9K $\pm$ 0.05%, 1/8W	1-945040-003	04387	Type WWA13		
R5	Resistor, ww, non-inductive, 475 ohms $\pm$ 0.05%, 1/8W	1-945040-001	04387	Type WWA13		
R6	Resistor, ww, non-inductive, 950 ohms $\pm$ 0.05%, 1/8W	1-945040-002	04387	Type WWA13		
R7	Resistor, ww, non-inductive, 950 ohms $\pm$ 0.05%, 1/8W	1-945040-002	04387	Type WWA13		
R8	Resistor, ww, non-inductive, 475 ohms $\pm$ 0.05%, 1/8W	1-945040-001	04387	Type WWA13		
R9	Resistor, ww, non-inductive, 1.9K $\pm$ 0.05%, 1/8W	1-945040-002	04387	Type WWA13		
R10	Resistor, ww, non-inductive, 475 ohms $\pm$ 0.05%, 1/8W	1-945040-001	04387	Type WWA13		
R11	Resistor, selected value					
R12	*Resistor, selected value					
R13	Resistor, comp, 2.7K $\pm$ 10%, 1/4W	1-945000-042	01121	Type CB		
S1	Switch, degree (not shown)		88869	4-402863-001		

COMPONENT SIDE

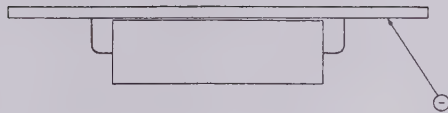
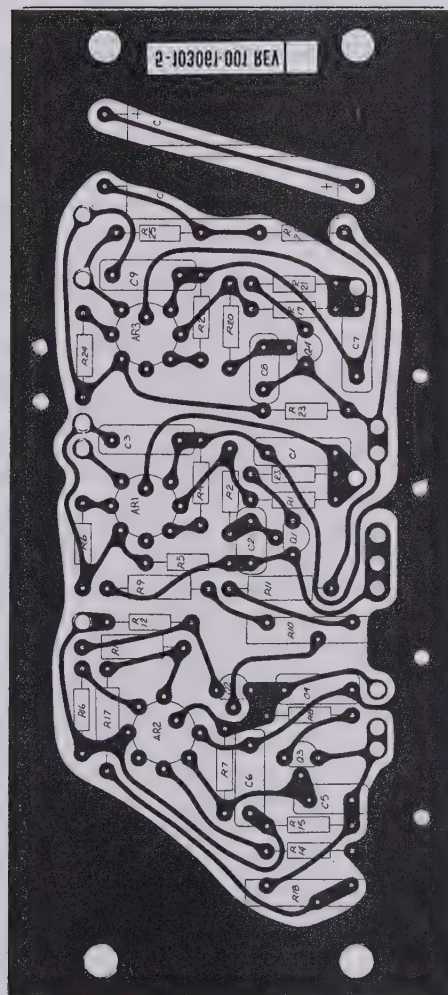


Figure 6-3. Quadrature Circuit Board Assembly

FIGURE 6-3.
QUADRATURE CIRCUIT BOARD A2

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
AR1	IC, Diff. cascade amp.	1-926005-001	79089	CA3028		
AR2	IC, Diff. cascade amp.	1-926005-001	79089	CA3028		
AR3	IC, Diff. cascade amp.	1-926005-001	79089	CA3028		
C1	Capacitor, plastic, 0.1uf $\pm$ 20%, 250 vdcw	1-900001-013	73445	Type C280AE		
C2	Capacitor, mica, 150pf $\pm$ 5%, 500 vdcw	1-900003-034	72136	DM15F151J		
C3	Capacitor, plastic, 0.1uf $\pm$ 20%, 250 vdcw	1-900001-013	73445	Type C280AE		
C4	Capacitor, plastic, 0.1uf $\pm$ 20%, 250 vdcw	1-900001-013	73445	Type C280AE		
C5	Capacitor, mica, 22pf $\pm$ 5%, 500vdcw	1-900003-013	72136	DM15E220J		
C6	Capacitor, plastic, 0.1uf $\pm$ 20%, 250 vdcw	1-900001-013	73445	Type C280AE		
C7	Capacitor, plastic, 0.1uf $\pm$ 20%, 250 vdcw	1-900001-013	73445	Type C280AE		
C8	Capacitor, mica, 22pf $\pm$ 5%, 500vdcw	1-900003-013	72136	DM15E220J		
C9	Capacitor, plastic, 0.1uf $\pm$ 20%, 250 vdcw	1-900001-013	73445	Type C280AE		
C10	Capacitor, electrolytic, 200uf, 15vdcw	1-900039-002	76433	974-141		
C11	Capacitor, electrolytic, 200uf, 15vdcw	1-900039-002	76433	974-141		
Q1	Transistor	1-958000-002	04713	2N3906		
Q2	Transistor	1-958000-001	04713	2N3904		
Q3	Transistor	1-958000-002	04713	2N3906		
Q4	Transistor	1-958000-002	04713	2N3906		
R1	Resistor, comp, 3.3K $\pm$ 10%, 1/4W	1-945000-043	01121	Type CB		
R2	Resistor, comp, 10 ohms $\pm$ 10%, 1/4W	1-945000-013	01121	Type CB		
R3	Resistor, comp, 100 ohms $\pm$ 10%, 1/4W	1-945000-025	01121	Type CB		
R4	Resistor, comp, 10K $\pm$ 10%, 1/4W	1-945000-049	01121	Type CB		
R5	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-045	01121	Type CB		
R6	Resistor, comp, 1K $\pm$ 10%, 1/4W	1-945000-037	01121	Type CB		

REF DESIG	DESCRIPTOIN	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R7	Resistor, comp, 3.3K $\pm$ 10%, 1/4W	1-945000-043	01121	Type CB		
R8	Resistor, comp, 10 ohms $\pm$ 10%, 1/4W	1-945000-013	01121	Type CB		
R9	Resistor, film, 4.99K $\pm$ 1%, 1/4W	1-945016-260		Type RN60D		
R10	Resistor, variable, 10K	1-945039-010	02660	3800 P103		
R11	Resistor, film, 4.99K $\pm$ 1%, 1/4W	1-945016-260		Type RN60D		
R12	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-045	01121	Type CB		
R13	Resistor, film, 10K $\pm$ 1%, 1/4W	1-945016-289		Type RN60D		
R14	Resistor, comp, 1K $\pm$ 10%, 1/4W	1-945000-037	01121	Type CB		
R15	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-045	01121	Type CB		
R16	Resistor, comp, 1K $\pm$ 10%, 1/4W	1-945000-037	01121	Type CB		
R17	Resistor, film, 9.53K $\pm$ 1%, 1/4W	1-945016-287		Type RN60D		
R18	Resistor, variable, 1K	1-945039-007	02660	3800 P102		
R19	Resistor, comp, 3.3K $\pm$ 10%, 1/4W	1-945000-043	01121	Type CB		
R20	Resistor, comp, 10 ohms $\pm$ 10%, 1/4W	1-945000-013	01121	Type CB		
R21	Resistor, comp, 47 ohms $\pm$ 10%, 1/4W	1-945000-021	01121	Type CB		
R22	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-045	01121	Type CB		
R23	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-045	01121	Type CB		
R24	Resistor, comp, 1K $\pm$ 10%, 1/4W	1-945000-037	01121	Type CB		
R25	Resistor, comp, 10K $\pm$ 10%, 1/4W	1-945000-049	01121	Type CB		
R26	Resistor, comp, 10K $\pm$ 10%, 1/4W	1-945000-049	01121	Type CB		

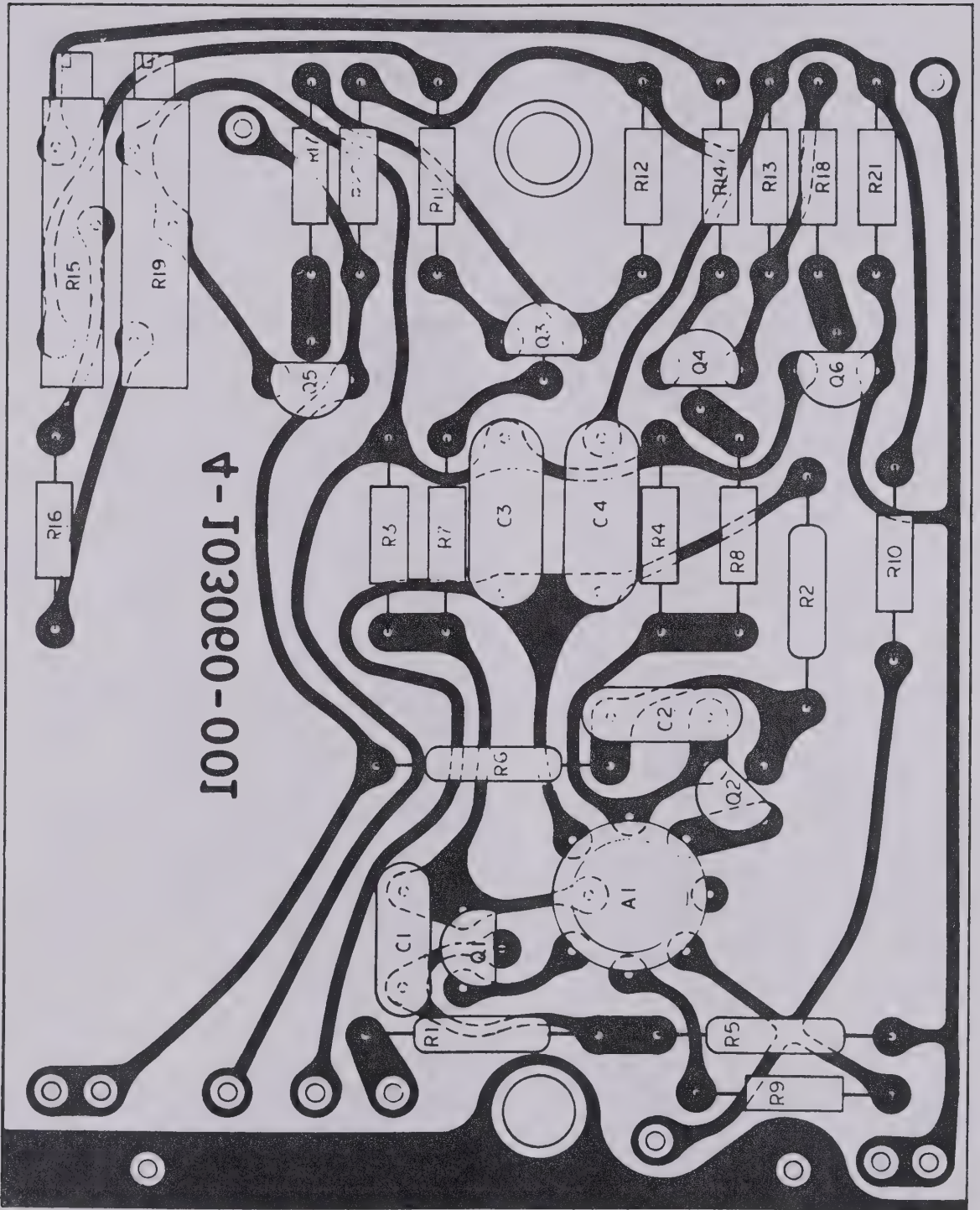


Figure 6-4. Circuit Board Assembly, Quad, X5

FIGURE 6-4.
QUADRATURE X5 CIRCUIT BOARD A3

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
AR1	IC, Diff. cascade amp.	1-926005-001	79089	CA 3028		
C1	Capacitor, mica, 10pf $\pm 5\%$, 500vdcw	1-900003-008	72136	DM15C100J		
C2	Capacitor, mica, 10pf $\pm 5\%$, 500vdcw	1-900003-008	72136	DM15C100J		
C3	Capacitor, plastic, 0.1uf $\pm 20\%$, 250vdcw	1-900001-013	73445	Type C280AE		
C4	Capacitor, plastic, 0.1uf $\pm 20\%$, 250vdcw	1-900001-013	73445	Type C280AE		
Q1	Transistor	1-958000-001	04713	2N3904		
Q2	Transistor	1-958000-001	04713	2N3904		
Q3	Transistor	1-958000-002	04713	2N3906		
Q4	Transistor	1-958000-002	04713	2N3906		
Q5	Transistor	1-958000-001	04713	2N3904		
Q6	Transistor	1-958000-001	04713	2N3904		
R1	Resistor, film, 10K $\pm 1\%$, 1/4W	1-945016-289		Type RN60D		
R2	Resistor, film, 20K $\pm 1\%$, 1/4W	1-945016-318		Type RN60D		
R3	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R4	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R5	Resistor, film, 200K $\pm 1\%$, 1/4W	1-945016-414		Type RN60D		
R6	Resistor, film, 200K $\pm 1\%$, 1/4W	1-945016-414		Type RN60D		
R7	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R8	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R9	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R10	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R11	Resistor, comp, 47 ohms $\pm 10\%$, 1/4W	1-945000-021	01121	Type CB		
R12	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R13	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R14	Resistor, comp, 47 ohms $\pm 10\%$, 1/4W	1-945000-021	01121	Type CB		
R15	Resistor, variable, 500 ohms	1-945039-004	02660	3800 P101		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV4A	PAV-4B
R16	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R17	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R18	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R19	Resistor, variable, 200 ohms	1-945039-006	02660	3800 P501		
R20	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R21	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		

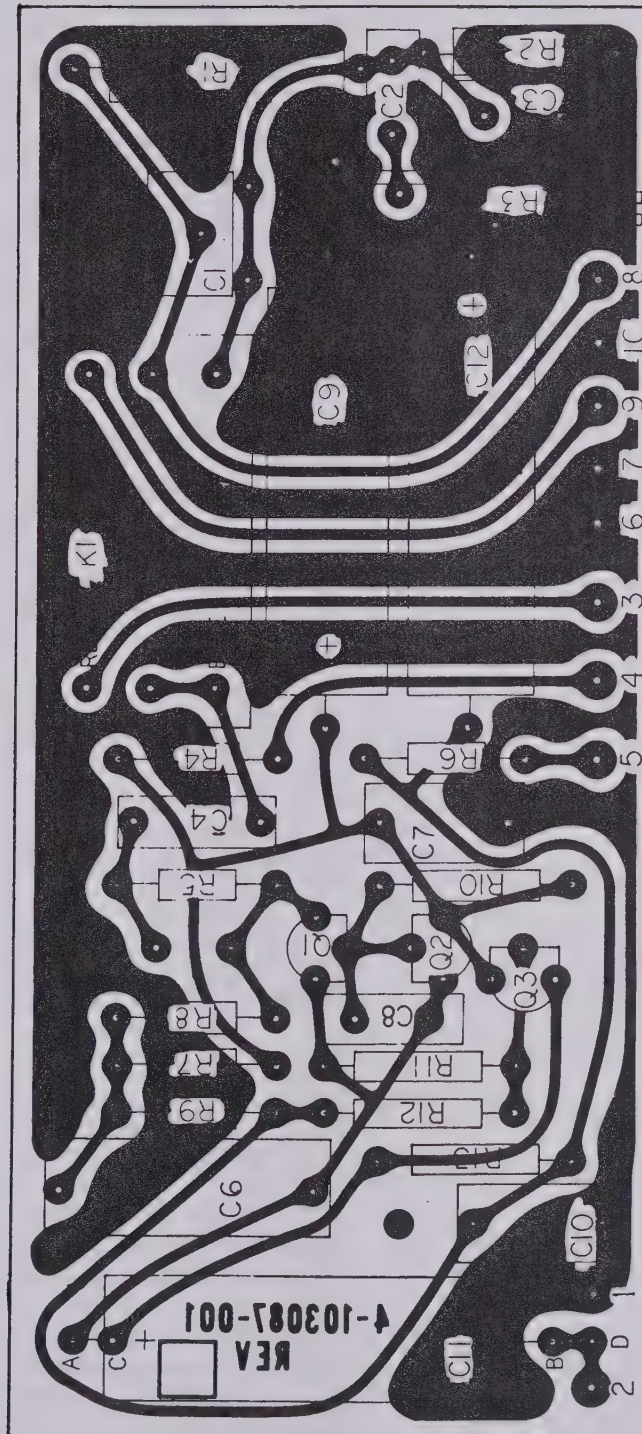


Figure 6-5. Circuit Board Assembly, Ref Input

FIGURE 6-5.
REFERENCE INPUT CIRCUIT BOARD A4

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
C1	Capacitor, variable, 2 - 8pf	1-900021-001	15450	538-006COPO-89R		
C2	Capacitor, mica, 300pf $\pm 5\%$, 500vdcw	1-900003-013	72136	DM15E301J		
C3	Capacitor, mica, 470pf $\pm 5\%$, 500vdcw	1-900003-047	72136	DM15F471J		
C4	Capacitor, plastic, 0.01uf $\pm 20\%$, 250vdcw	1-900001-001	73445	Type C280AE		
C5	Not used					
C6	Capacitor, plastic, 0.47uf $\pm 20\%$, 250vdcw	1-900001-021	73445	Type C280AE		
C7	Capacitor, plastic, 0.1uf $\pm 20\%$,	1-900001-013	73445	Type C280AE		
C8	Capacitor, mica, 22pf $\pm 5\%$, 500vdcw	1-900003-013	72136	DM15E220J		
C9	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C10	Capacitor, plastic, 0.1uf $\pm 20\%$, 250vdcw	1-900001-013	73445	Type C280AE		
C11	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C12	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
CR1	Diode, Silicon	1-913007-001	03508	1N4148		
CR2	Diode, silicon	1-913007-001	03508	1N4148		
K1	Relay, reed		88869	1-402791-001		
Q1	Transistor, FET	1-958002-003	04713	E102		
Q2	Transistor, PNP	1-958000-002	04713	2N3906		Q4
Q3	Transistor, NPN	1-958000-001	04713	2N3904		
Q4	Transistor, NPN	1-958000-002	04713	2N3906	B	
R1	Resistor, film, 10 meg $\pm 1\%$, 1/2W	1-945044-577	00327	Type M12		
R2	Resistor, film, 100K $\pm 1\%$, 1/4W	1-945016-385		Type RN60D		
R3	Resistor, variable, 2K	1-945039-008	02660	3800 P202		
R4	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R5	Resistor, comp, 39K $\pm 10\%$, 1/4W	1-945000-056	01121	Type CB		
R6	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R7	Resistor, comp, 470K $\pm 10\%$, 1/4W	1-945000-069	01121	Type CB	A	1M
R7	Resistor, comp, 1M $\pm 10\%$, 1/4W	1-945000-	01121	Type CB		B
R8	Resistor, comp, 3.3 meg $\pm 10\%$, 1/4W	1-945000-079	01121	Type CB		
R9	Resistor, comp, 470K $\pm 10\%$, 1/4W	1-945000-069	01121	Type CB	A	1.2M
R9	Resistor, comp, 1.2M $\pm 10\%$, 1/4W	1-945000-	01121	Type CB		B
R10	Resistor, film, 1K $\pm 1\%$, 1/4W	1-945016-193		Type RN60D		
R11	Resistor, film, 499 ohms $\pm 1\%$, 1/4W	1-945016-164		Type RN60D	A	
R11	Resistor, film, 22 ohms $\pm 1\%$, 1/4W			Type RN60D		B
R12	Resistor, film, 332 ohms $\pm 1\%$, 1/4W	1-945016-147		Type RN60D	A	
R12	Resistor, film, 10K $\pm 1\%$, 1/4W			Type RN60D		B
R13	Resistor, film, 499 ohms $\pm 1\%$, 1/4W	1-945016-164		Type RN60D	A	
R13	Resistor, film, 220 ohms $\pm 1\%$, 1/4W			Type RN60D		B

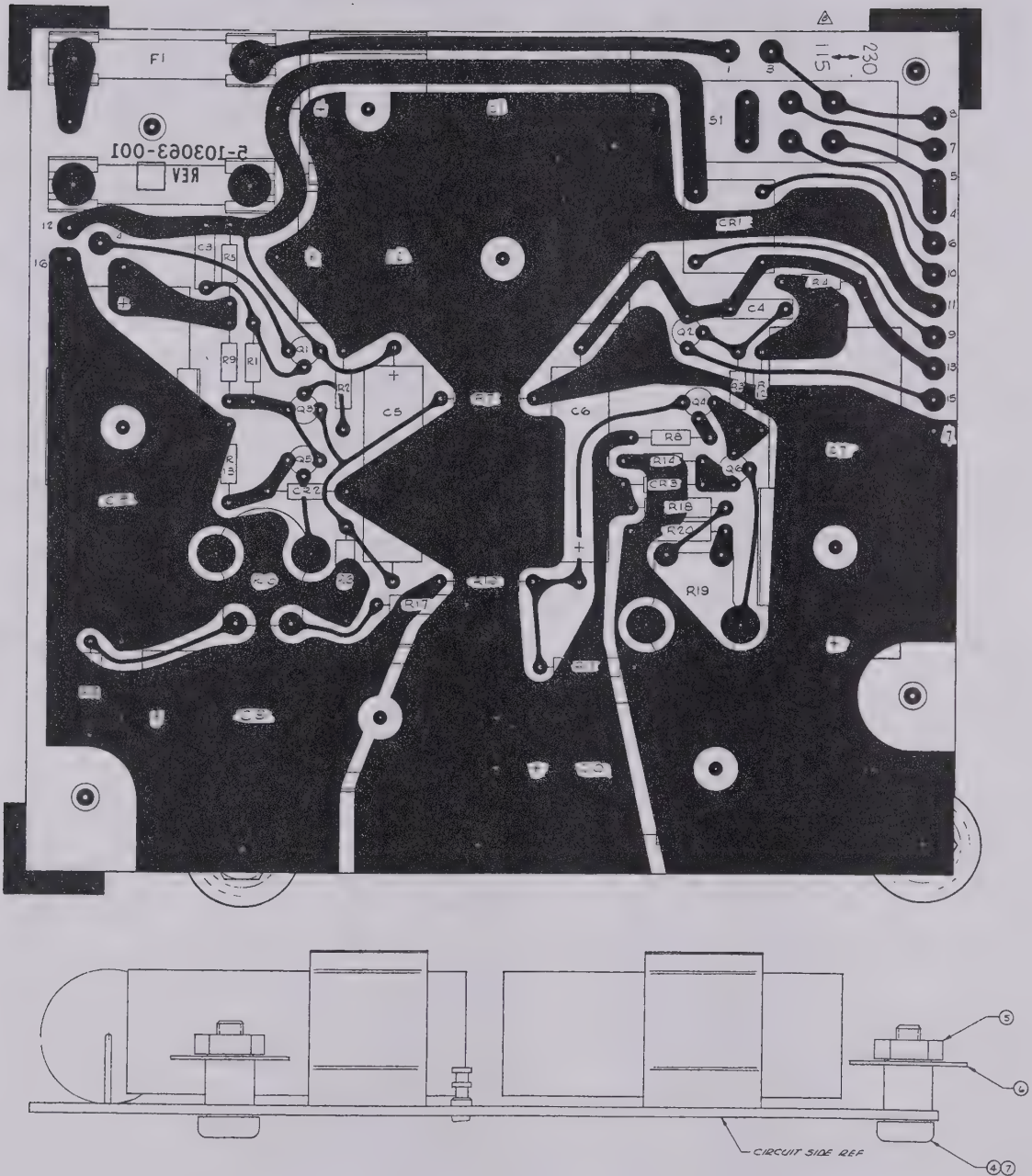


Figure 6-6. Circuit Board Assembly, Power Supply

FIGURE 6-6.
POWER SUPPLY CIRCUIT BOARD A5

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
C1	Capacitor, elect, 1500uf, 25vdcw	1-900040-002	76433	977-206		
C2	Capacitor, elect, 1500uf, 25vdcw	1-900040-002	76433	977-206		
C3	Capacitor, mica, 680pf $\pm 5\%$, 300vdcw	1-900003-052	72136	DM15F681J		
C4	Capacitor, mica, 680pf $\pm 5\%$, 300vdcw	1-900003-052	72136	DM15F681J		
C5	Capacitor, elect, 150uf, 25vdcw	1-900039-003	76433	974-143		
C6	Capacitor, elect, 150uf, 25vdcw	1-900039-003	76433	974-143		
C7	Capacitor, elect, 1500uf, 25vdcw	1-900040-002	76433	977-206		
C8	Capacitor, elect, 1500uf, 25vdcw	1-900040-002	76433	977-206		
C9	Capacitor, elect, 1500uf, 25vdcw	1-900040-002	76433	977-206		
C10	Capacitor, elect, 1500uf, 25vdcw	1-900040-002	76433	977-206		
CR1	Rectifier Bridge, 2 amp	1-913006-001	02101	VS 248		
CR2	Diode, Zener, 6.2V	1-913004-208	04713	Type MZ		
CR3	Diode, Zener, 6.2V	1-913004-208	04713	Type MZ		
F1	Fuse, 1/2 amp	1-924000-014	03614	Type MDL		
Q1	Transistor	1-958022-001	79089	40450		
Q2	Transistor	1-958023-002	79089	2N4037		
Q3	Transistor	1-958000-001	04713	2N3904		
Q4	Transistor	1-958000-002	04713	2N3906		
Q5	Transistor	1-958000-001	04713	2N3904		
Q6	Transistor	1-958000-002	04713	2N3906		
R1	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R2	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R3	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R4	Resistor, comp, 470 ohms $\pm 10\%$, 1/4W	1-945000-033	01121	Type CB		
R5	Resistor, comp, 470 ohms $\pm 10\%$, 1/4W	1-945000-033	01121	Type CB		
R6	Resistor, comp, 560 ohms $\pm 10\%$, 1/2W	1-945001-034	01121	Type EB		
R7	Resistor, comp, 1K $\pm 10\%$, 1/2W	1-945001-037	01121	Type EB		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R8	Resistor, comp, 1K $\pm$ 10%, 1/4W	1-945000-037	01121	Type CB		
R9	Resistor, comp, 2.2K $\pm$ 10%, 1/4W	1-945000-041	01121	Type CB		
R10	Resistor, comp, 1K $\pm$ 10%, 1/2W	1-945001-037	01121	Type EB		
R11	Resistor, comp, 560 ohms $\pm$ 10%, 1/2W	1-945001-034	01121	Type EB		
R12	Resistor, comp, 2.2K $\pm$ 10%, 1/4W	1-945000-041	01121	Type CB		
R13	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-045	01121	Type CB		
R14	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-045	01121	Type CB		
R15	Resistor, film, 499 ohms $\pm$ 1%, 1/4W	1-945016-164		Type RN60D		
R16	Resistor, variable, 500 ohms $\pm$ 30%, 1/4W	1-945010-003	71450	Type U 201		
R17	Resistor, film, 499 ohms $\pm$ 1%, 1/4W	1-945016-164		Type RN60D		
R18	Resistor, film, 499 ohms $\pm$ 1%, 1/4W	1-945016-164		Type RN60D		
R19	Resistor, variable, 500 ohms $\pm$ 30%, 1/4W	1-945010-003	71450	Type U 201		
R20	Resistor, film, 499 ohms $\pm$ 1%, 1/4W	1-945016-164		Type RN60D		
S1	Switch, slide, DPDT	1-951003-002	82389	Type 46206 LF		

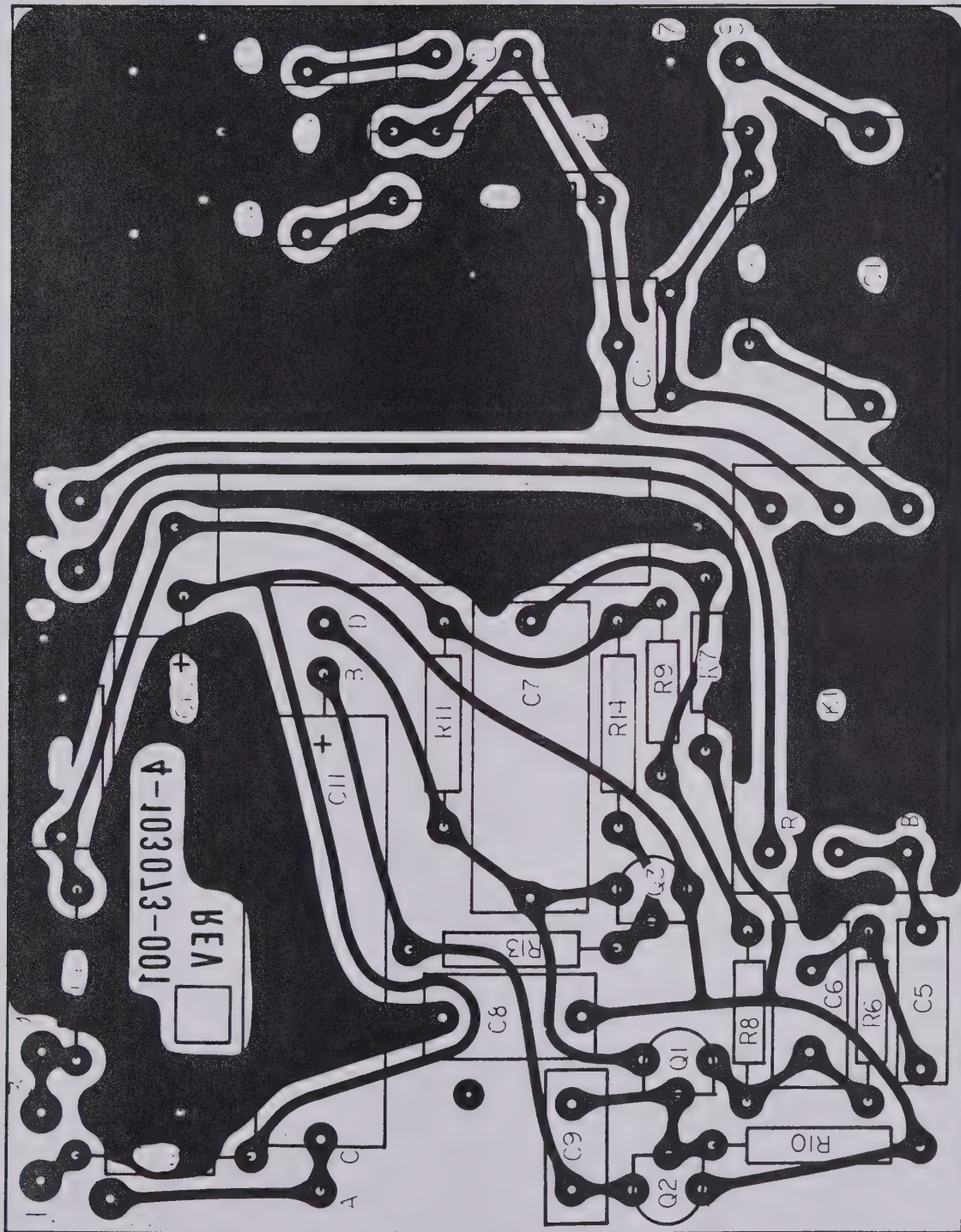


Figure 6-7. Circuit Board Assembly, Signal Input

FIGURE 6-7
SIGNAL INPUT CIRCUIT BOARD A6

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
C1	Capacitor, plastic, 0.1uf $\pm$ 20%, 630V	1-900043-013	73445	Type C280CG		
C2	Capacitor, variable, 2 to 8pf	1-900021-001	15450	538-006COP- O89R		
C3	Capacitor, mica, 1000pf $\pm$ 5%, 500vdcw	1-900003-038	72136	DM15F102J		
C4	Capacitor, plastic, 0.0015uf $\pm$ 5%	1-900041-003	12406	B5A152J		
C5	Capacitor, plastic, 0.01uf $\pm$ 20%, 250vdcw	1-900001-001	73445	Type C280AE		
C6	Capacitor, mica, 47pf $\pm$ 5%, 500vdcw	1-900003-047	72136	DM15F470J		
C7	Capacitor, plastic, 0.47uf $\pm$ 20%, 250vdcw	1-900001-021	73445	Type C280AE		
C8	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C9	Capacitor, mica, 22pf $\pm$ 5%, 500vdcw	1-900003-013	72136	DM15E220J		
C10	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C11	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C12	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C13	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
CR1	Diode,	1-913001-001		1N4148		
CR2	Diode	1-913007-001		1N4148		
K1	Relay, reed		88869	1-402791-001		
Q1	Transistor, FET	1-958031-003	17856	E 102		
Q2	Transistor, PNP	1-958000-002	04713	2N3906		
Q3	Transistor, NPN	1-958000-001	04713	2N3904		
Q4	Transistor, PNP	1-958000-002	04713	2N3906		
R1	Resistor, comp, 10 ohms $\pm$ 10%, 1/4W	1-945000-013	01121	Type CB		
R2	Resistor, film, 10 meg $\pm$ 1%, 1/2W	1-945044-577	00327	Type M12		
R3	Resistor, film, 30.9K $\pm$ 1%, 1/4W	1-945016-336		Type RN60D		
R4	Resistor, variable, ww, 2K	1-945039-008	02660	3800P 202		
R5	Resistor, variable, ww, 2K	1-945039-008	02660	3800P 202		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R6	Resistor, comp, 39K $\pm 10\%$, 1/4W	1-945000-056	01121	Type CB		
R7	Resistor, comp, 1 meg $\pm 10\%$, 1/4W	1-945000-073	01121	Type CB		
R8	Resistor, comp, 3.3 meg $\pm 10\%$, 1/4W	1-945000-079	01121	Type CB		
R9	Resistor, comp, 330 $\pm 10\%$, 1/4W	1-945000-xxx	01121	Type CB	A	
R9	Resistor, comp, 1.2 meg $\pm 10\%$, 1/4W		01121	Type CB		B
R10	Resistor, film, 1K $\pm 1\%$, 1/4W	1-945016-193		Type RN60D		
R11	Resistor, film, 499 ohms $\pm 1\%$, 1/4W	1-945016-xxx		Type RN60D	A	
R11	Resistor, film, 22 ohms $\pm 1\%$, 1/4W			Type RN60D		B
R12	Resistor, comp, 150 ohms $\pm 10\%$, 1/4W	1-945000-xxx	01121	Type CB		
R13	Resistor, film, 499 ohms $\pm 1\%$, 1/4W	1-945016-164		Type RN60D	A	
R13	Resistor, film, 220 ohms $\pm 1\%$, 1/4W			Type RN60D		B
R14	Resistor, film, 332 ohms $\pm 1\%$, 1/4W	1-945016-147		Type RN60D	A	
R14	Resistor, film, 10K $\pm 1\%$, 1/4W			Type RN60D		B
R15	Resistor, comp, 150 ohms $\pm 10\%$, 1/4W	1-945000-xxx	01121	Type CB		

NOTES:
1. CIRCUITRY SHOWN FOR REF ONLY.

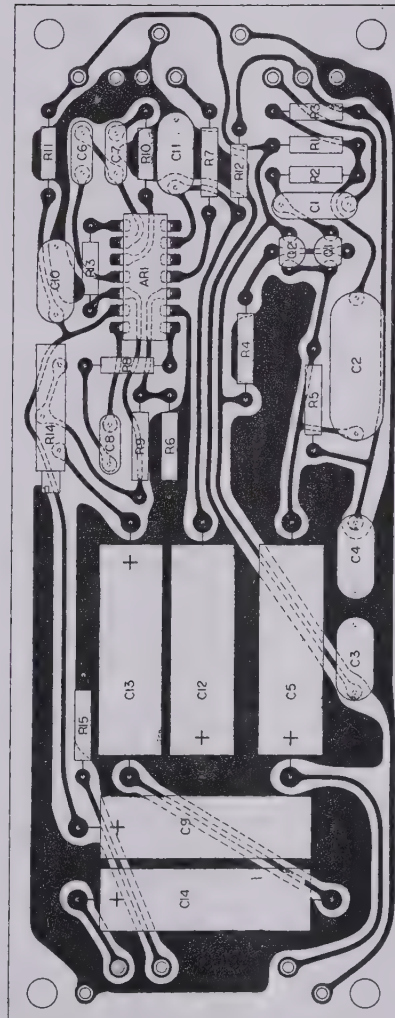


Figure 6-8. Circuit Board Assembly, X30 Signal

**FIGURE 6-8
X30 SIGNAL CIRCUIT BOARD A7**

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
AR1	IC, Operational Amplifier	1-926006-001	79089	CA 3030		
C1	Capacitor, plastic, 0.01uf $\pm$ 20%, 250vdcw	1-900001-001	73445	Type C280AE		
C2	Capacitor, plastic, 0.47uf $\pm$ 20%, 250vdcw	1-900001-021	73445	Type C280AE		
C3	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C4	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C5	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C6	Capacitor, mica, 10pf $\pm$ 5%, 500vdcw	1-900003-008	72136	DM15C100J		
C7	Capacitor, mica, 10pf $\pm$ 5%, 500vdcw	1-900003-008	72136	DM15C100J		
C8	Capacitor, mica, 10pf $\pm$ 5%, 500vdcw	1-900003-008	72136	DM15C100J		
C9	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C10	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C11	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C12	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C13	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C14	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
Q1	Transistor, FET	1-958002-003	04713	MPF 105-5		
Q2	Transistor	1-958000-002	04713	2N3906		
R1	Resistor, comp, 2.2 meg $\pm$ 10%, 1/4W	1-945000-077	01121	Type CB		
R2	Resistor, comp, 3.3 meg $\pm$ 10%, 1/4w	1-945000-079	01121	Type CB		
R3	Resistor, comp, 220K $\pm$ 10%, 1/4W	1-945000-065	01121	Type CB		
R4	Resistor, film, 1K $\pm$ 1%, 1/4W	1-945016-193		Type RN60D		
R5	Resistor, film, 2K $\pm$ 1%, 1/4W	1-945016-222		Type RN60D		
R6	Resistor, film, 200 ohms $\pm$ 1%, 1/4W	1-945016-126		Type RN60D		
R7	Resistor, film, 200 ohms $\pm$ 1%, 1/4W	1-945016-126		Type RN60D		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R8	Resistor, comp, 680 ohms $\pm 10\%$, 1/4W	1-945000-035	01121	Type CB		
R9	Resistor, film, 6.04K $\pm 1\%$, 1/4W	1-945016-268		Type RN60D		
R10	Resistor, comp, 680 ohms $\pm 10\%$, 1/4W	1-945000-035	01121	Type CB		
R11	Resistor, comp, 390 ohms $\pm 10\%$, 1/4W	1-945000-032	01121	Type CB		
R12	Resistor, comp, 390 ohms $\pm 10\%$, 1/4W	1-945000-032	01121	Type CB		
R13	Resistor, comp, 4.7K $\pm 10\%$, 1/4W	1-945000-045	01121	Type CB		
R14	Resistor, variable, ww, 200 ohms	1-945039-005	02660	3800 P201		
R15	Resistor, film, 200 ohms $\pm 1\%$, 1/4W	1-945016-126		Type RN60D		

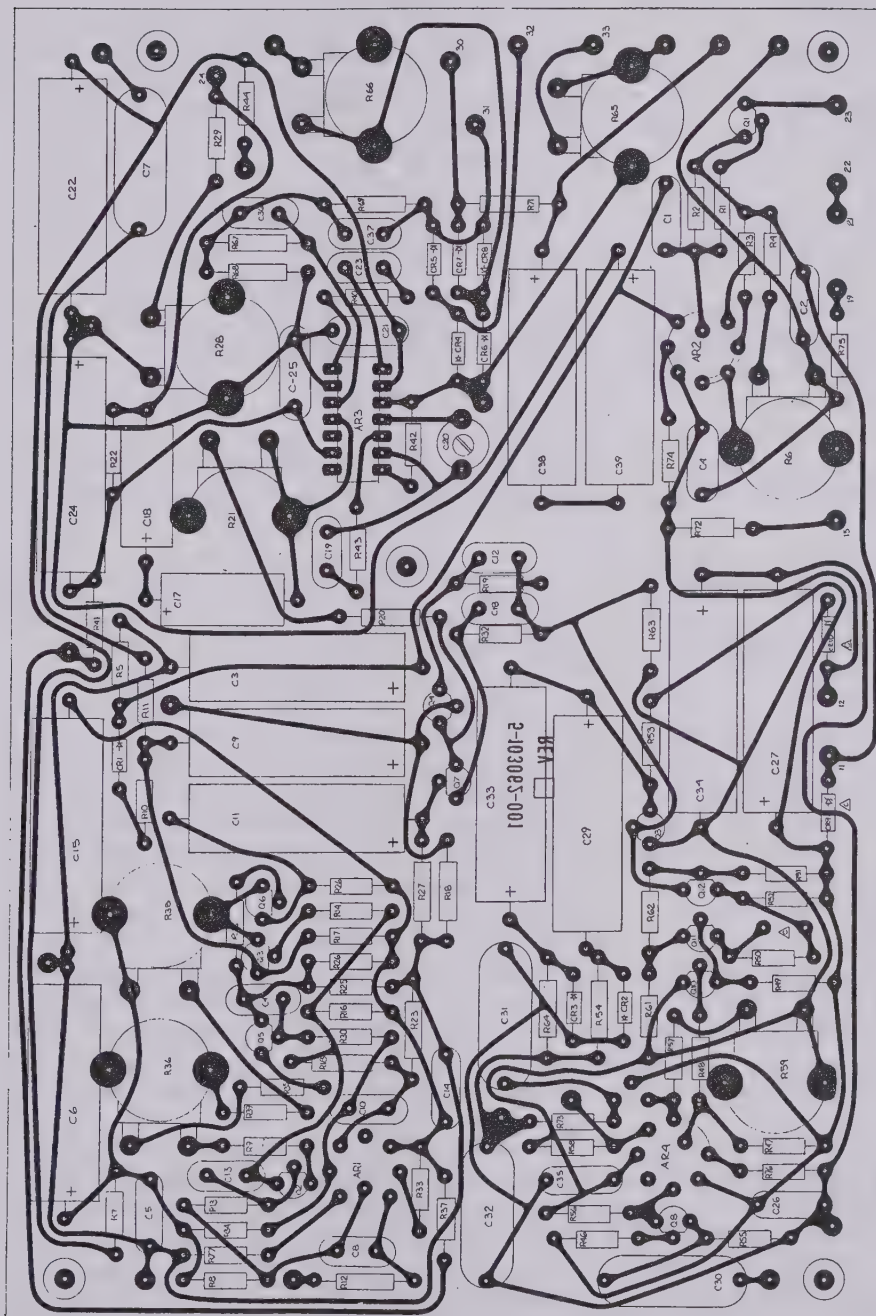


Figure 6-9. Circuit Board, Detector

FIGURE 6-9
DETECTOR CIRCUIT BOARD A8

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
AR1	IC, Diff. cascade amp.	1-926005-001	79089	CA 3028		
AR2	IC, Diff. cascade amp.	1-926005-001	79089	CA 3028		
AR3	IC, Operational amplifier	1-926006-001	79089	CA 3030		
AR4	IC, Diff. cascade amp.	1-926005-001	79089	CA 3028		
C1	Capacitor, plastic, 0.01uf $\pm$ 20%, 250vdcw	1-900001-001	73445	Type C280AE		
C2	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C3	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C4	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C5	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C6	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C7	Capacitor, plastic, 0.47uf $\pm$ 20%, 250vdcw	1-900001-021	73445	Type C280AE		
C8	Capacitor, mica, 10pf $\pm$ 5%, 500vdcw	1-900003-008	72136	DM15C100J		
C9	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C10	Capacitor, mica, 10pf $\pm$ 5%, 500vdcw	1-900003-008	72136	DM15C100J		
C11	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C12	Capacitor, mica, 22pf $\pm$ 5%, 500vdcw	1-900003-013	72136	DM15E220J		
C13	Capacitor, mica, 22pf $\pm$ 5%, 500vdcw	1-900003-013	72136	DM15E220J		
C14	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C15	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C16	Capacitor, mica, 22pf $\pm$ 5%, 500vdcw	1-900003-013	72136	DM15E220J		
C17	Capacitor, elect, 25uf, 25vdcw	1-900039-001	76433	974-118		
C18	Capacitor, elect, 25uf, 25vdcw	1-900039-001	76433	974-141		
C19	Capacitor, mica, 10pf $\pm$ 5%, 500vdcw	1-900003-008	72136	DM15C100J		
C20	Capacitor, variable, 5-18pf	1-900031-002	15450	538-011-5.5- 18PFA		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
C21	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C22	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C23	Capacitor, mica, 10pf $\pm$ 5%, 500vdcw	1-900003-008	72136	DM15C100J		
C24	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C25	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C26	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C27	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C28	Capacitor, ceramic disc, 0.005uf, 500vdcw	1-900012-004	15450	801Z5U502Z		
C29	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C30	Capacitor, plastic, 0.47uf $\pm$ 20%, 250vdcw	1-900001-021	73445	Type C280AE		
C31	Capacitor, plastic, 0.47uf $\pm$ 20%, 250vdcw	1-900001-021	73445	Type C280AE		
C32	Capacitor, plastic, 0.47uf $\pm$ 20%, 250vdcw	1-900001-021	73445	Type C280AE		
C33	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C34	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C35	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C36	Capacitor, mica, 680pf $\pm$ 5%, 300vdcw	1-900003-052	72136	DM15F681J		
C37	Capacitor, mica, 68pf $\pm$ 5%, 500vdcw	1-900003-026	72136	DM15E680J		
C38	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C39	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C40	Capacitor, mica, 22pf $\pm$ 5%, 500vdcw	1-900003-013	72136	DM15E220J		
CR1	Diode, silicon	1-913007-001	03508	1N4148		
CR2	Diode, silicon	1-913007-001	03508	1N4148		
CR3	Diode, silicon	1-913007-001	03508	1N4148		
CR4	Diode, silicon	1-913007-001	03508	1N4148		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
CR5	Diode, silicon	1-913007-001	03508	1N4148		
CR6	Diode, silicon	1-913007-001	03508	1N4148		
CR7	Diode, silicon	1-913007-001	03508	1N4148		
CR8	Diode, silicon	1-913007-001	03508	1N4148		
CR9	Diode, Zener, 5.1V, 1W	1-913004-006	04713	Type MZ		
CR10	Diode, Zener, 5.1V, 1W	1-913004-006	04713	Type MZ		
Q1	Transistor	1-958000-002	04713	2N3906		
Q2	Transistor	1-958000-002	04713	2N3906		
Q3	Transistor	1-958000-001	04713	2N3904		
Q4	Transistor, FET	1-958002-003	04713	MPF 105-5		
Q5	Transistor	1-958000-002	04713	2N3906		
Q6	Transistor	1-958000-001	04713	2N3904		
Q7	Transistor, FET	1-958021-003	04713	MPF 153-5		
Q8	Transistor, FET	1-958002-003	04713	MPF 105-5		
Q9	Transistor, FET	1-958002-003	04713	MPF 105-5		
Q10	Transistor	1-958000-002	04713	2N3906		
Q11	Transistor	1-958000-002	04713	2N3906		
Q12	Transistor	1-958000-002	04713	2N3906		
Q13	Transistor	1-958000-002	04713	2N3906		
R1	Resistor, comp, 1K $\pm$ 10%, 1/4W	1-945000-037	01121	Type CB		
R2	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-009	01121	Type CB		
R3	Resistor, comp, 2.2K $\pm$ 10%, 1/4W	1-945000-041	01121	Type CB		
R4	Resistor, comp, 6.8K $\pm$ 10%, 1/4W	1-945000-047	01121	Type CB		
R5	Resistor, comp, 4.7K $\pm$ 10%, 1/4W	1-945000-045	01121	Type CB		
R6	Resistor, variable, 5K $\pm$ 30%, 1/4W	1-945010-006	71450	Type U201		
R7	Resistor, comp, 100 ohms $\pm$ 10%, 1/4W	1-945000-025	01121	Type CB		
R8	Resistor, comp, 2.2K $\pm$ 10%, 1/4W	1-945000-041	01121	Type CB		
R9	Resistor, comp, 47 ohms $\pm$ 10%, 1/4W	1-945000-021	01121	Type CB		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R10	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R11	Resistor, comp, 10K $\pm 10\%$, 1/4W	1-945000-049	01121	Type CB		
R12	Resistor, film, 2K $\pm 1\%$, 1/4W	1-945016-222		Type RN50D		
R13	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R14	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R15	Resistor, film, 20K $\pm 1\%$, 1/4W	1-945016-318		Type RN60D		
R16	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R17	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R18	Resistor, film, 1K $\pm 1\%$, 1/4W	1-945016-193		Type RN60D		
R19	Resistor, comp, 2.2 meg $\pm 10\%$, 1/4W	1-945000-077	01121	Type CB		
R20	Resistor, film, 1K $\pm 1\%$, 1/4W	1-945016-193		Type RN60D		
R21	Resistor, variable, 1K $\pm 30\%$, 1/4W	1-945010-004	71450	Type U201		
R22	Resistor, comp, 2.2 meg $\pm 10\%$, 1/4W	1-945000-077	01121	Type CB		
R23	Resistor, film, 2K $\pm 1\%$, 1/4W	1-945016-222		Type RN60D		
R24	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-053	01121	Type CB		
R25	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R26	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R27	Resistor, comp, 1K $\pm 1\%$, 1/4W	1-945016-193		Type RN60D		
R28	Resistor, variable, 1K $\pm 30\%$, 1/4W	1-945010-004	71450	Type U201		
R29	Resistor, comp, 470 ohms $\pm 10\%$, 1/4W	1-945000-033	01121	Type CB		
R30	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R31	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R32	Resistor, comp, 2.2 meg $\pm 10\%$, 1/4W	1-945000-077	01121	Type CB		
R33	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R34	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R35	Resistor, comp, 47 ohms $\pm 10\%$, 1/4W	1-945000-021	01121	Type CB		
R36	Resistor, variable, 100 ohms $\pm 30\%$, 1/4W	1-945010-001	71450	Type U201		
R37	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R38	Resistor, variable, 500 ohms $\pm 30\%$, 1/4W	1-945010-003	01121	Type CB		

REFDESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R39	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R40	Resistor, comp, 680 ohms $\pm 10\%$, 1/4W	1-945000-035	01121	Type CB		
R41	Resistor, comp, 150 ohms $\pm 10\%$, 1/4W	1-945000-027	01121	Type CB		
R42	Resistor, comp, 4.7K $\pm 10\%$, 1/4W	1-945000-009	01121	Type CB		
R43	Resistor, comp, 680 ohms $\pm 10\%$, 1/4W	1-945000-035	01121	Type CB		
R44	Resistor, comp, 150 ohms $\pm 10\%$, 1/4W	1-945000-027	01121	Type CB		
R45	Not Used					
R46	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R47	Resistor, comp, 3.9K $\pm 10\%$, 1/4W	1-945000-044	01121	Type CB		
R48	Resistor, comp, 10 ohms $\pm 10\%$, 1/4W	1-945000-013	01121	Type CB		
R49	Resistor, comp, 4.7K $\pm 10\%$, 1/4W	1-945000-009	01121	Type CB		
R50	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R51	Resistor, comp, 10K $\pm 10\%$, 1/4W	1-945000-049	01121	Type CB		
R52	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R53	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R54	Resistor, film, 100K $\pm 1\%$, 1/4W	1-945016-385		Type RN60D		
R55	Resistor, comp, 1 meg $\pm 10\%$, 1/4W	1-945000-073	01121	Type CB		
R56	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R57	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R58	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R59	Resistor, variable, 10K $\pm 30\%$, 1/4W	1-945010-007	71450	Type U201		
R60	Not Used					
R61	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R62	Resistor, comp, 22K $\pm 10\%$, 1/4W	1-945000-053	01121	Type CB		
R63	Resistor, comp, 2.2K $\pm 10\%$, 1/4W	1-945000-041	01121	Type CB		
R64	Resistor, film, 100K $\pm 1\%$, 1/4W	1-945016-385		Type RN60D		
R65	Resistor, variable, 1K $\pm 30\%$, 1/4W	1-945010-004	71450	Type U201		
R66	Resistor, variable, 1K $\pm 30\%$, 1/4W	1-945010-004	71450	Type U201		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
R67	Resistor, film, 2.43K $\pm$ 1%, 1/4W	1-945016-230		Type RN60D		
R68	Resistor, film, 200 ohms $\pm$ 1%	1-945016-126		Type RN60D		
R69	Resistor, film, 1K $\pm$ 1%, 1/4W	1-945016-193		Type RN60D		
R70	Resistor (Not Used)					
R71	Resistor, film 332 ohms $\pm$ 1%, 1/4W	1-945016-147		Type RN60D		
R72	Resistor, comp, 330 ohms $\pm$ 10%, 1/4W	1-945000-031	01121	Type CB		
R73	Resistor, comp, 1 meg $\pm$ 10%, 1/4W	1-945000-073	01121	Type CB		
R74	Resistor, comp, 1.5K $\pm$ 10%, 1/4W	1-945000-039	01121	Type CB		
R75	Resistor, comp, 330 ohms $\pm$ 10%, 1/4W	1-945000-031	01121	Type CB		
R76	Resistor, comp, 10 ohms $\pm$ 10%, 1/4W	1-945000-013	01121	Type CB		
R77	Resistor, comp, 10 ohms $\pm$ 10%, 1/4W	1-945000-013	01121	Type CB		

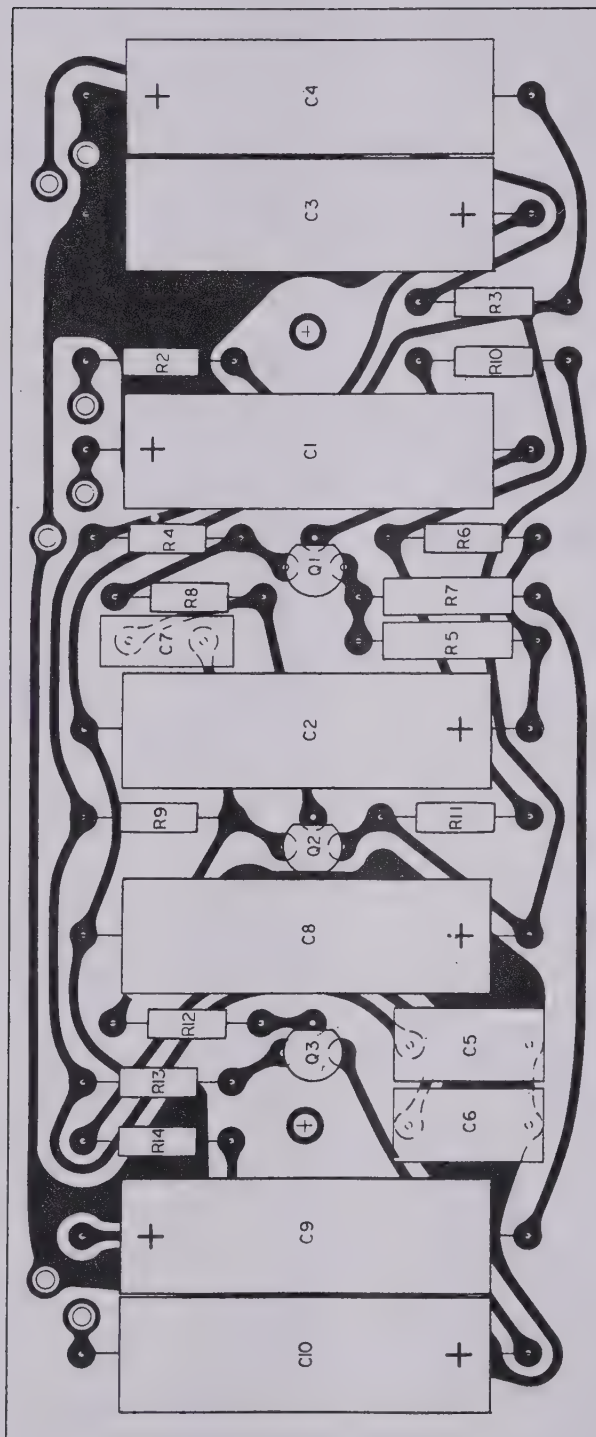


Figure 6-10. Circuit Board Assembly, Reference X5

FIGURE 6-10
REFERENCE X5 CIRCUIT BOARD A9

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
C1	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C2	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C3	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C4	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C5	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C6	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdcw	1-900001-013	73445	Type C280AE		
C7	Capacitor, mica, 10pf $\pm$ 5%, 500vdcw	1-900003-008	72136	DM15C100J		
C8	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C9	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C10	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
Q1	Transistor	1-958000-001	04713	2N3904		
Q2	Transistor	1-958000-001	04713	2N3904		
Q3	Transistor	1-958000-001	04713	2N3904		
R1	Resistor (Not Used)					
R2	Resistor, comp, 220 ohms $\pm$ 10%, 1/4W	1-945000-029	01121	Type CB		
R3	Resistor, comp, 220 ohms $\pm$ 10%, 1/4W	1-945000-029	01121	Type CB		
R4	Resistor, comp, 8.2K $\pm$ 10%, 1/4W	1-945000-048	01121	Type CB		
R5	Resistor, film, 1K $\pm$ 1%, 1/4W	1-945016-193		Type RN60D		
R6	Resistor, comp, 1.5K $\pm$ 10%, 1/4W	1-945000-039	01121	Type CB		
R7	Resistor, film, 4.99K $\pm$ 1%, 1/4W	1-945016-260		Type RN60D		
R8	Resistor, comp, 10 ohms $\pm$ 10%, 1/4W	1-945000-013	01121	Type CB		
R9	Resistor, comp, 3.3K $\pm$ 10%, 1/4W	1-945000-043	01121	Type CB		
R10	Resistor, comp, 27K $\pm$ 10%, 1/4W	1-945000-054	01121	Type CB		
R11	Resistor, comp, 2.2K $\pm$ 10%, 1/4W	1-945000-041	01121	Type CB		
R12	Resistor, comp, 10 ohms $\pm$ 10%, 1/4W	1-945000-013	01121	Type CB		
R13	Resistor, comp, 47 ohms $\pm$ 10%, 1/4W	1-945000-021	01121	Type CB		
R14	Resistor, comp, 2.2K $\pm$ 10%, 1/4W	1-945000-041	01121	Type CB		

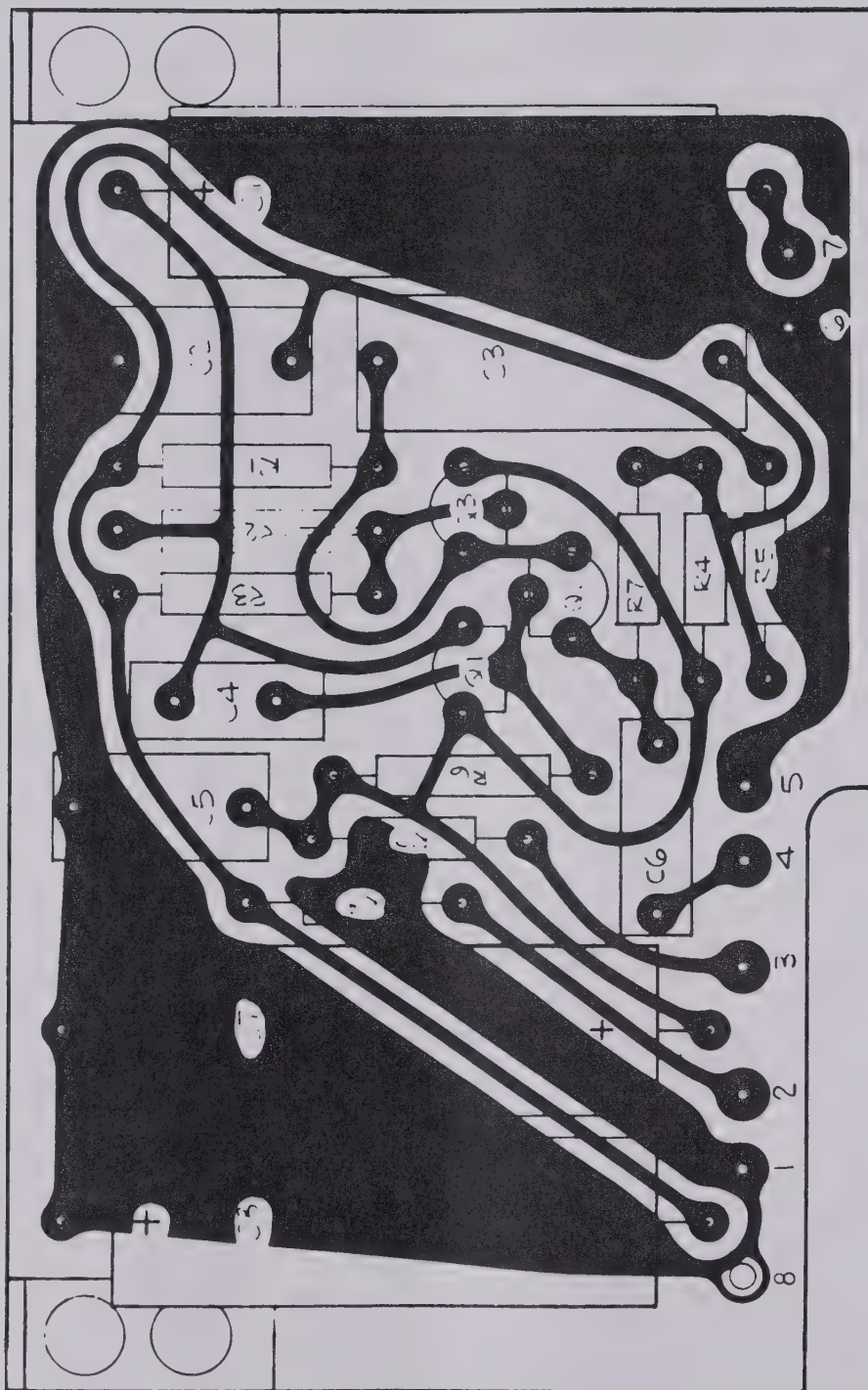


Figure 6-11. Circuit Board Assembly, Isolation Input

FIGURE 6-11
ISOLATION INPUT CIRCUIT BOARD A10, A12

REF/DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
C1	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		B
C2	Capacitor, plastic, 0.1uf $\pm 20\%$, 250vdcw	1-900001-013	73445	Type C280AE		B
C3	Capacitor, plastic, 0.47uf $\pm 20\%$, 250vdcw	1-900001-021	73445	Type C280AE		B
C4	Capacitor, mica, 22pf $\pm 5\%$, 500vdcw	1-900003-013	72136	DM15E220J		B
C5	Capacitor, plastic, 0.1uf $\pm 20\%$, 250vdcw	1-900001-013	73445	Type C280AE		B
C6	Capacitor, plastic, 0.01uf $\pm 20\%$, 250vdcw	1-900001-001	73445	Type C280AE		B
C7	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		B
C8	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		B
Q1	Transistor, PNP	1-958000-002	04713	2N3906		B
Q2	Transistor, FET	1-958031-003		E 102		B
Q3	Transistor, NPN	1-958000-001	04713	2N3904		B
A10R1	Resistor, film, 1K $\pm 1\%$, 1/4W	1-945016-193		Type RN60D		B
A12R1	Resistor, film, 4.99K $\pm 10\%$, 1/4W	1-945016-xxx		Type RN60D		B
A10R2	Resistor, film, 499 ohms $\pm 1\%$, 1/4W	1-945016-164		Type RN60D		B
A12R2	Not Used					B
A10R3	Resistor, film, 332 ohms $\pm 1\%$, 1/4W	1-945016-147		Type RN60D		B
A12R3	Resistor, comp, 680 ohms $\pm 10\%$, 1/2W		01121	Type EB		B
R4	Resistor, comp, 1 meg $\pm 10\%$, 1/4W	1-945000-073	01121	Type CB		B
A10R5	Resistor, comp, 220K $\pm 10\%$, 1/4W	1-945000-065	01121	Type CB		B
A12R5	Resistor, comp, 1.5M $\pm 10\%$, 1/4W		01121	Type CB		B
R6	Resistor, film, 1K $\pm 1\%$, 1/4W	1-945016-193		Type RN60D		B
R7	Resistor, comp, 3.3 meg $\pm 10\%$, 1/4W	1-945000-0791	01121	Type CB		B
R8	Resistor, comp, 220 ohms $\pm 10\%$, 1/4W	1-945000-079	01121	Type CB		B
R9	Resistor, comp, 220 ohms $\pm 10\%$, 1/4W	1-945000-029	01121	Type CB		B

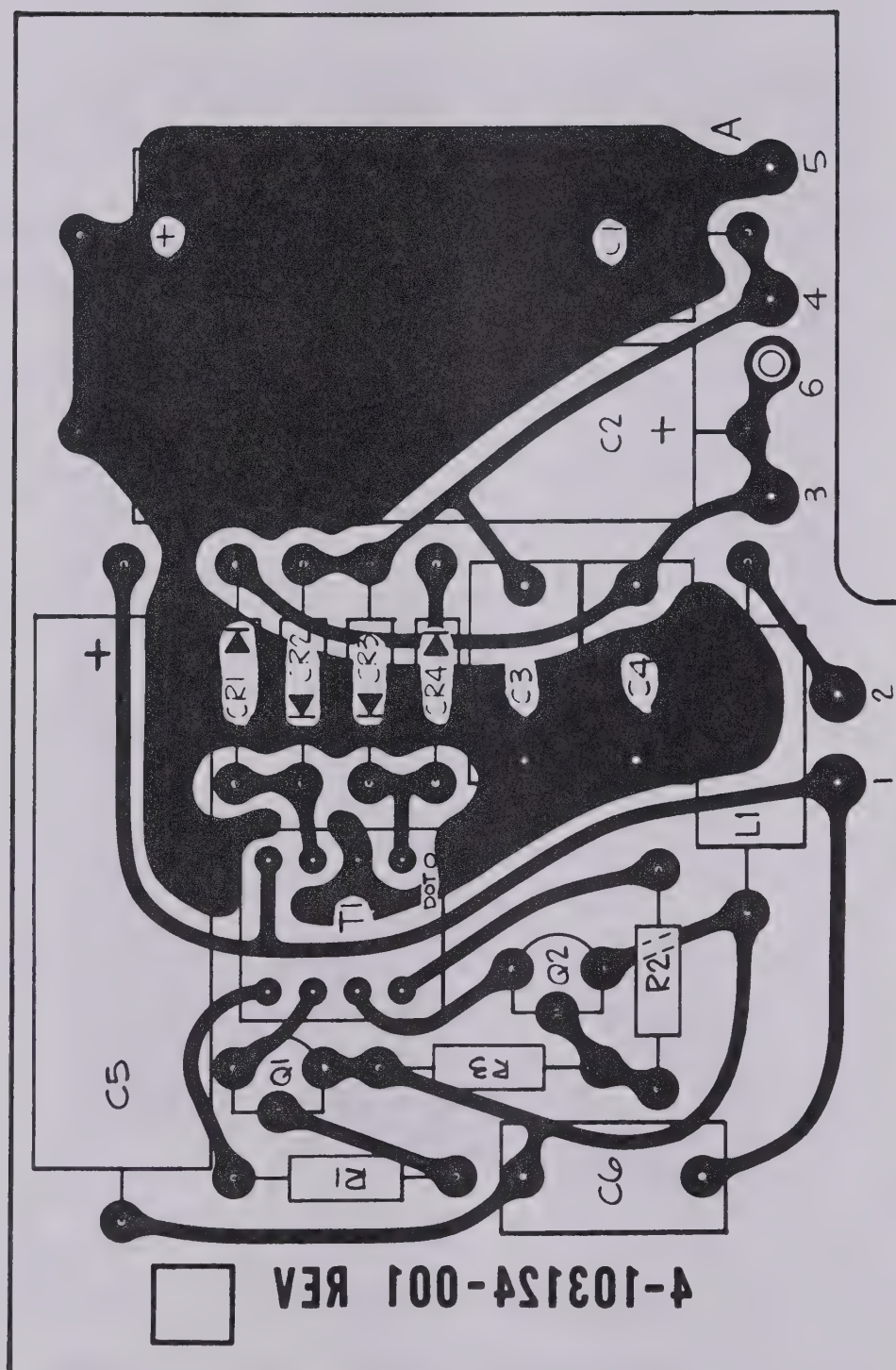


Figure 6-12. Circuit Board Assembly, Isolation Inverter

FIGURE 6-12
ISOLATION INVERTER CIRCUIT BOARD A11, A13

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
C1	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C2	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C3	Capacitor, plastic, 0.1uf $\pm 20\%$, 250vdcw	1-900001-013	73445	Type C280AE		
C4	Capacitor, plastic, 0.1uf $\pm 20\%$, 250vdcw	1-900001-013	73445	Type C280AE		
C5	Capacitor, elect, 200uf, 15vdcw	1-900039-002	76433	974-141		
C6	Capacitor, plastic, 0.1uf $\pm 20\%$, 250vdcw	1-900001-013	73445	Type C280AE		
CR1	Diode	1-913000-001	01295	1N914		
CR2	Diode	1-913000-001	01295	1N914		
CR3	Diode	1-913000-001	01295	1N914		
CR4	Diode	1-913000-001	01295	1N914		
L1	Choke, 1mh	1-906007-003	04213	670-3		
Q1	Transistor, PNP	1-958000-002	04713	2N3906		
Q2	Transistor, PNP	1-958000-002	04713	2N3906		
R1	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R2	Resistor, comp, 1K $\pm 10\%$, 1/4W	1-945000-037	01121	Type CB		
R3	Resistor, comp, 22K $\pm 10\%$, 1/4W	1-945000-053	01121	Type CB		
T1	Transformer		88869	1-402894-001		

SECTION VIII

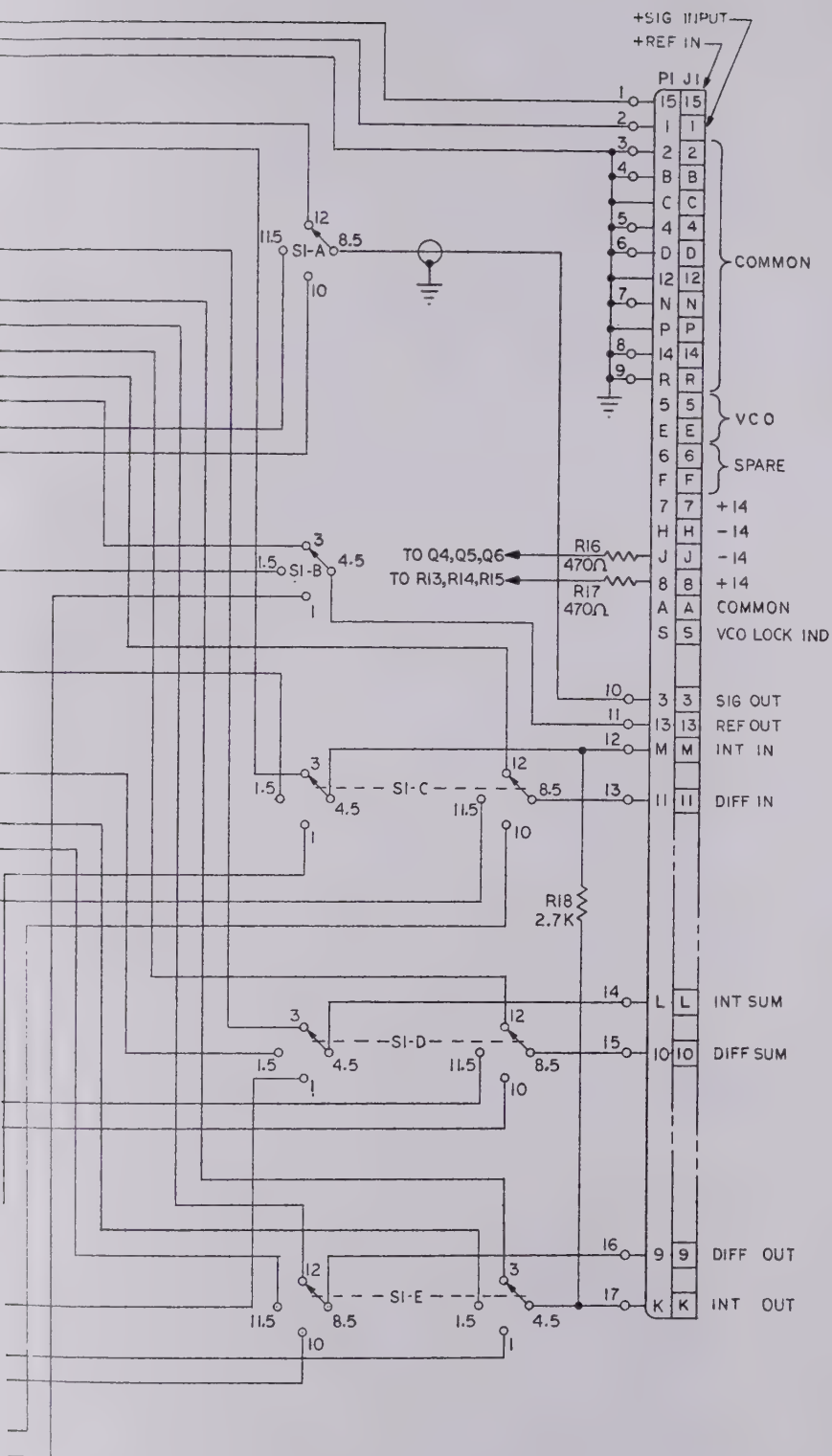
MULTIPLE FREQUENCY MODULE

8-1. DESCRIPTION

8-2. Refer to paragraphs 1-10 and 4-11 for a description of the module. Refer to paragraph 5-17 for adjustments. Refer to figure 8-1 for schematic.

8-3. PARTS LIST.

8-4. Refer to paragraphs 6-1 through 6-4 for parts list application.



NOTES: (UNLESS OTHERWISE SPECIFIED)

1. VALUE OF COMPONENTS DESIGNATED THUS

* TO BE SELECTED ON ASSEMBLY 1-002744-

2. SWITCH SI SHOWN IN CW POSITION, ALL DECKS (A THRU E) ROTATE ON A COMMON SHAFT.

3. POSITIONS 1, 2 & 3 EACH CONSIST OF A MATCHED SET OF FILTERS (SIG & REF), THE NETWORK BOARD AND ASSOCIATED MOTHER BOARD CIRCUITRY.

4. RESISTOR VALUES IN OHMS, TOLERANCE $\pm 10\%$, $1/4W$, UNLESS OTHERWISE SPECIFIED.

5. LAST REF DESIGNATOR USED ON NETWORK CIRCUIT BOARDS: C3, R11

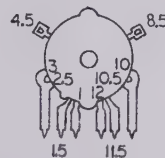
6. LAST REF DESIGNATOR USED ON MOTHER CIRCUIT BOARD: C6, FL6, J4, Q6 & R18.

7. CIRCUITRY CORRESPONDING TO POSITIONS 1, 2 & 3 BRACKETS, REPRESENT THOSE COMPONENTS ON ASSY 4-002752-001 AND ARE LABELED AS SUCH ON SAID ASSY.

8. NETWORK BOARD RESISTORS R6 & R9 MAY NOT BE REQD ON ASSY.

9. ALL COMPONENTS WHOSE LOCATIONS NOT SPECIFIED ARE LOCATED ON MOTHER CIRCUIT BOARD.

10. SHOWN BELOW IS SI (SWITCH) ORIENTATION AND TERM IDENTIFICATION, FOR REF ONLY.



VIEWED FROM KNOB END

11. J1 IS SHOWN FOR REF ONLY.

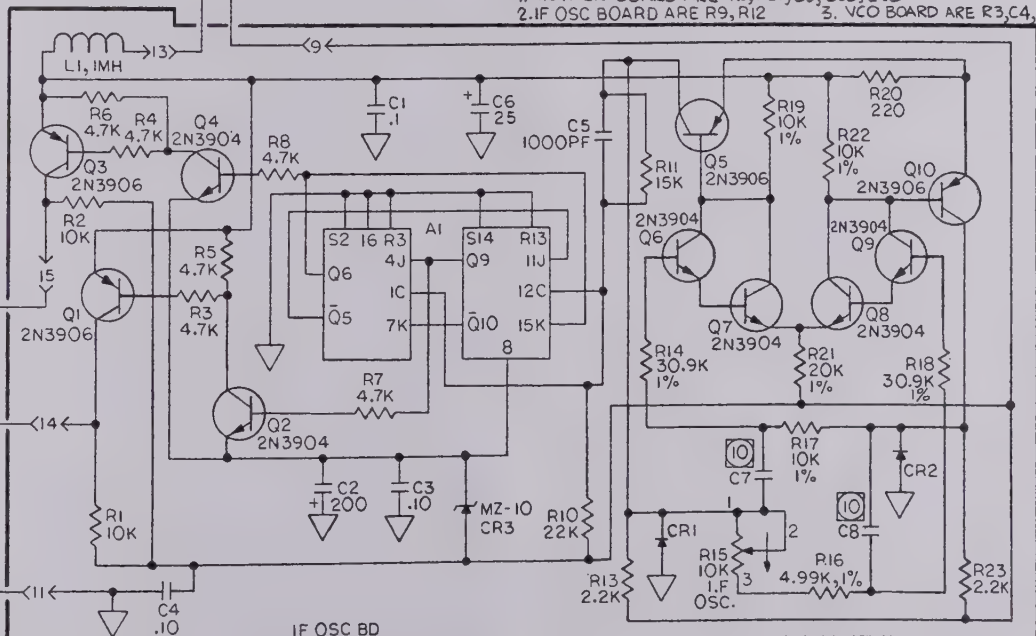
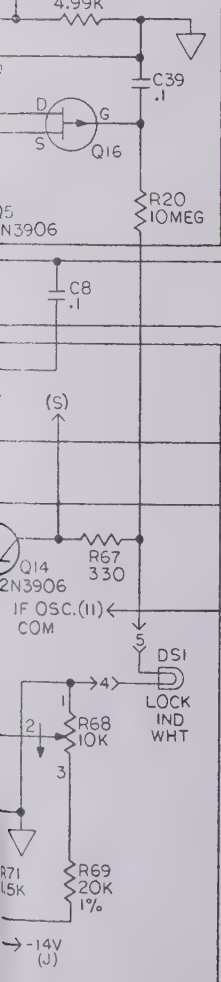
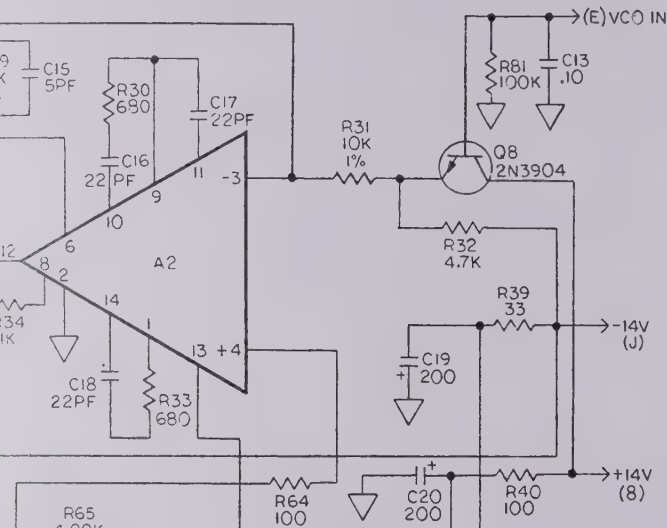
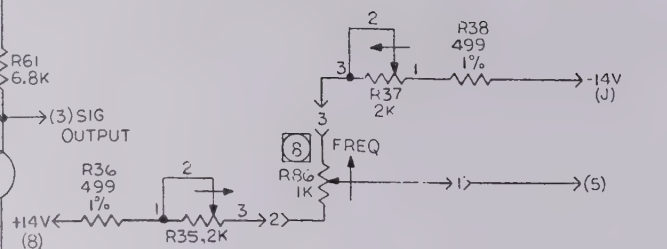
SECTION IX

VARIABLE FREQUENCY MODULE

9-1. DESCRIPTION

for a description of the module. Refer to paragraph 5-18 for adjustments. Refer to figure 9-1 for schematic diagram.

9-2. Refer to paragraphs 1-11, 1-12, 4-14, and 4-15



NOTES: UNLESS OTHERWISE SPECIFIED

1. RESISTOR VALUES IN OHMS, TOLERANCE $\pm 10\%$, 1/4 WATT.
2. CAPACITOR VALUES IN MICROFARADS.
3. DIODES ARE TYPE IN4148.
4. ARROWS THRU POTENTIOMETER WIPERS INDICATE CW ROTATION.
5. NUMBER AND LETTERS IN PARENTHESES INDICATE CONNECTOR (J) ON PAV) PIN DESIGNATIONS.
6. COMPONENTS ARE MOUNTED ON MOTHER BOARD EXCEPT THOSE ENCLOSED WITHIN A HEAVY PHANTOM LINE.
7. COMPONENTS ENCLOSED WITHIN A HEAVY PHANTOM LINE ARE MOUNTED ON INDIVIDUAL PLUG-IN BOARDS DESIGNATED VCO AND IF OSC.
8. POTENTIOMETER R86 AND IND LAMP DSI ARE MOUNTED ON FRONT PANEL OF CHASSIS.
9. LAST REFERENCE DESIGNATIONS USED ON:
 1. MOTHER BOARD ARE R89, Q16, C44, A4, CR1, FL2, TP4, L1
 2. VCO BOARD ARE R11, C10, Q7, CR4, L1, A1
 3. IF OSC BOARD ARE R23, Q10, C8, CR3, L1, A1
10. TABULATED BELOW ARE CAPACITOR VALUE DIFFERENCES FOR MODEL VF1 AND VF2.

MOTHER BOARD		VCO BOARD	
CAPACITOR	VALUE	CAPACITOR	VALUE
C2, C5	22	VF1	VF2
C2	—	C2, C5	.015 500PF
C14	.039	IF OSC BOARD	
C30	.47	CAPACITOR	VALUE
C37, C40	20UF	VF1	VF2
L1	—	C7, C8	.1 3000PF
C31, C32	.15UF 4700 PF		

11. REFERENCE DESIGNATIONS OMITTED:
 1. MOTHER BOARD ARE R9, R21, C3, C30, C38
 2. IF OSC BOARD ARE R9, R12
 3. VCO BOARD ARE R3, C4, C6

SECTION VII

SINGLE FREQUENCY MODULE

7-1. DESCRIPTION

7-2. Refer to paragraphs 1-9 and 4-11 for a description of the module. Refer to paragraph 5-16 for adjustments. Refer to figure 7-1 for schematic.

7-3. PARTS LIST.

7-4. Refer to paragraphs 6-1 through 6-4 for parts list application.

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
A1	Network Board, determined by frequency		88869	1-002274-xxx		
C1	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdc	1-900001-013	73445	Type C280AE		
C2	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdc	1-900001-013	73445	Type C280AE		
FL1	Filter, determined by frequency		88869	1-402798-xxx		
FL2	Filter, determined by frequency		88869	1-402798-xxx		
J2	Connector	1-910070-103				
Q1	Transistor	1-958000-001	04713	2N3904		
Q2	Transistor	1-958000-002	04713	2N3906		
R1	Resistor, comp, 10K $\pm$ 10%, 1/4W	1-945000-049	01121	Type CB		
R2	Resistor, comp, 100 ohms $\pm$ 10%, 1/4W	1-945000-025	01121	Type CB		
R3	Resistor, comp, 3.3K $\pm$ 10%, 1/4W	1-945000-043	01121	Type CB		
R4	Resistor, comp, 100 ohms $\pm$ 10%, 1/4W	1-945000-025	01121	Type CB		
R5	Resistor, comp, 3.3K $\pm$ 10%, 1/4W	1-945000-043	01121	Type CB		
R6	Resistor, comp, 1.5K $\pm$ 10%, 1/4W	1-945000-039	01121	Type CB		
R7	Resistor, comp, 1.5K $\pm$ 10%, 1/4W	1-945000-039	01121	Type CB		
R8	Resistor, comp, 2.7K $\pm$ 10%, 1/4W	1-945000-042	01121	Type CB		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV-4A	PAV-4B
A1	Network Board, frequency position No. 3; specify frequency		88869	1-002744-xxx		
A2	Network Board, frequency position No. 2; specify frequency		88869	1-002744-xxx		
A3	Network Board, frequency position No. 1; specify frequency		88869	1-002744-xxx		
C1	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdc	1-900001-013	73445	Type C280AE		
C2	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdc	1-900001-013	73445	Type C280AE		
C3	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdc	1-900001-013	73445	Type C280AE		
C4	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdc	1-900001-013	73445	Type C280AE		
C5	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdc	1-900001-013	73445	Type C280AE		
C6	Capacitor, plastic, 0.1uf $\pm$ 20%, 250vdc	1-900001-013	73445	Type C280AE		
FL1	Filter, signal channel, position No. 3; specify frequency		88869	1-402798-xxx		
FL2	Filter, reference channel, position No. 3; specify frequency		88869	1-402798-xxx		
FL3	Filter, signal channel, position No. 2; specify frequency		88869	1-402798-xxx		
FL4	Filter, reference channel, position No. 2; specify frequency		88869	1-402798-xxx		
FL5	Filter, signal channel position No. 1; specify frequency		88869	1-402798-xxx		
FL6	Filter, reference channel, position No. 1; specify frequency		88869	1-402798-xxx		
J2	Connector	1-910070-003				
J3	Connector	1-910070-003				
J4	Connector	1-910070-003				
Q1	Transistor	1-958000-001	04713	2N3904		
Q2	Transistor	1-958000-001	04713	2N3904		
Q3	Transistor	1-958000-001	04713	2N3904		
Q4	Transistor	1-958000-001	04713	2N3906		
Q5	Transistor	1-958000-002	04713	2N3906		
Q6	Transistor	1-958000-002	04713	2N3906		

REF DESIG	DESCRIPTION	SINGER REF NO.	MFG CODE	MFG PART NO.	PAV4A	PAV4B
R1	Resistor, comp, 10K $\pm 10\%$, 1/4W	1-945000-049	01121	Type CB		
R2	Resistor, comp, 10K $\pm 10\%$, 1/4W	1-945000-049	01121	Type CB		
R3	Resistor, comp, 10K $\pm 10\%$, 1/4W	1-945000-049	01121	Type CB		
R4	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R5	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R6	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R7	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R8	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R9	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R10	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R11	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R12	Resistor, comp, 100 ohms $\pm 10\%$, 1/4W	1-945000-025	01121	Type CB		
R13	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R14	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R15	Resistor, comp, 3.3K $\pm 10\%$, 1/4W	1-945000-043	01121	Type CB		
R16	Resistor, comp, 470 ohms $\pm 10\%$, 1/4W	1-945000-033	01121	Type CB		
R17	Resistor, comp, 470 ohms $\pm 10\%$, 1/4W	1-945000-033	01121	Type CB		
R18	Resistor, comp, 2.7K $\pm 10\%$, 1/4W	1-945000-042	01121	Type CB		
S1	Switch, rotary		88869	4402862-001		

APPENDIX A APPLICATION DATA

A-1. BRIDGE CIRCUIT APPLICATION.

A-2. In a bridge circuit, the phase angle voltmeter operates as a phase sensitive null detector with a high tolerance to a quadrature component. The PAV may be combined with any Gertsch RatioTran to form the AC bridge circuit shown in figure A-1.

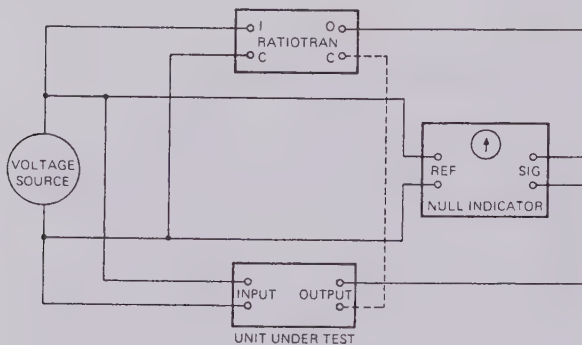


Figure A-1. AC Bridge Circuit

A-3. In this circuit, the PAV is set to 0 degree for detection of in-phase nulls. The RatioTran is adjusted until null is obtained. The in-phase, input-to-output voltage ratio of the unit under test may be read directly from the settings of the RatioTran.

The range control (VOLTS-RMS) of the PAV functions as a sensitivity control. If noise, harmonics, etc., obscure the null point, a higher range may be used. For more precise measurements, the lower ranges may be used.

A-4. The variable control of the PAV may be used for "go" "no-go" measurements. A typical procedure is as follows:

- a. Obtain an exact null at a selected reference point (0 degree output of unit-under-test, output at center frequency or center position of unit-under-test).
- b. Determine largest allowable deviation from this ratio setting. Offset the RatioTran by this amount.
- c. Through the use of the variable control, set this off-null voltage to equal a full-scale meter reading.
- d. Reset the RatioTran to the null point.
- e. In subsequent readings, any off-scale reading indicates "no-go". Any on-scale reading may be read as a direct percentage error.

A-5. The quadrature component of a phase-shifted signal can overload the signal circuits of the PAV and obscure the in-phase null. Assume an output vector voltage of 100 volts rms and a phase shift of 0.01 degrees. The sine of 0.01

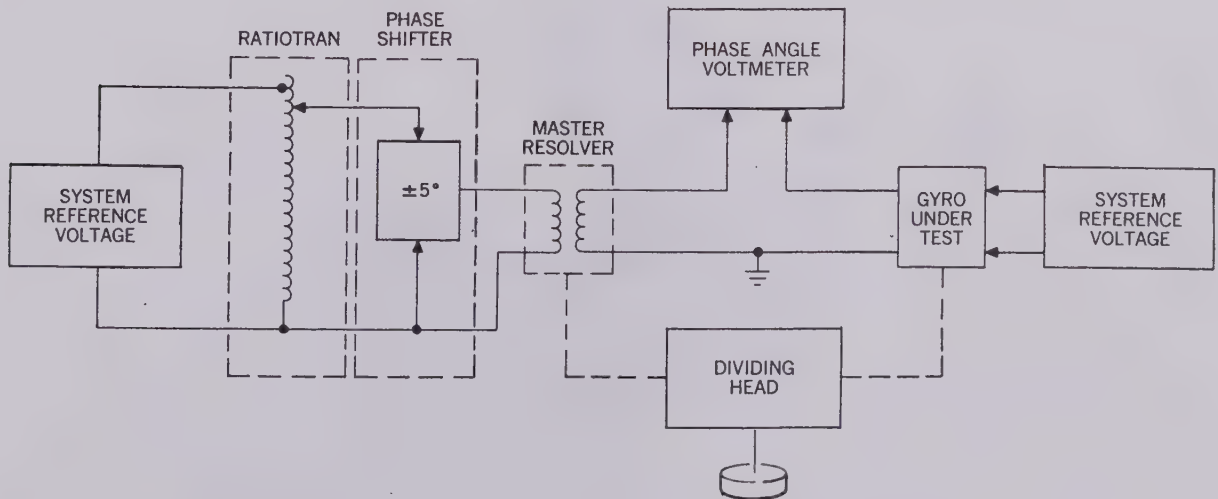


Figure A-2. Modified Bridge Circuit

degrees is 0.00017; 100×0.00017 results in a quadrature component of 17 millivolts. With the PAV operating in the 300uv or 1 millivolt range, this 17 millivolts represents an overload condition. The OVLD indicator would light although the meter would indicate null or near null. By switching to a higher range (less sensitivity), a more clearly defined null indication may be obtained.

A-6. Once null is obtained, a complete analysis of the output of the device under test may be made. The PAV may be operated in the 90 degree or FUND mode to measure quadrature voltage output. The PAV may be operated in the TOTAL mode to measure quadrature plus harmonic plus noise output.

A-7. MODIFIED BRIDGE CIRCUITS.

A-8. A typical modification of the bridge circuit is shown in figure A-2. In this circuit, the output of a gyro is compared against the output of a master resolver (null equals no error).

A-9. To compare the two units, some slight correction for phase shift and transformation ratio (RatioTran) are made. In this application the PAV is set to an angle equal to the phase shift through the master resolver.

A-10. Another modified bridge circuit is shown in figure A-3. This circuit is used to measure the functional accuracy of a computational resolver.

A-11. Functional accuracy is a measure of the accuracy with which a computational resolver computes a trigonometric equation. This accuracy is generally expressed as a percentage of the output at the point of maximum coupling. The output of a .1% computational resolver is maximum at 90 degrees for the sine function. The accuracy is therefore .001 times the voltage ($E_s \text{ MAX}$) at 90 degrees ($\sin \theta = 90^\circ$).

A-12. A dividing head is the precision angular positioning device used to mechanically rotate a unit under test. A resolver standard produces a $\sin \theta$ reference voltage to measure the computed output of the unit under test. All components may be tested at 5 degree increments throughout the 0 to 360 degree range.

A-13. The decade capacitor and the 1K resistor are used to compensate for any phase shift through the unit under test. These components are used to shift the phase of the reference input to the phase angle voltmeter and the resolver standard. The RatioTran by the same process compensates for any variation in transformation ratio through the unit under test.

A-14. SYNCHROS AND RESOLVERS

A-15. Most angular accuracy tests of synchros and resolvers use a bridge circuit which requires a phase sensitive null indicator, equipped with a calibrated phase shifter. The variable control is particularly useful when checking the output at 5 degree increments throughout the 360 degree range of the component. Null voltage readings may be made by switching the PAV to the fundamental or total modes. Transformation ratio may be determined with a RatioTran as shown in figure A-1. The calibrated phase shifter provides a readout of phase shift (θ) of the unit-under-test.

A-16. TRANSFER FUNCTION TESTS.

A-17. A typical transfer function test set-up is shown in Figure A-4.

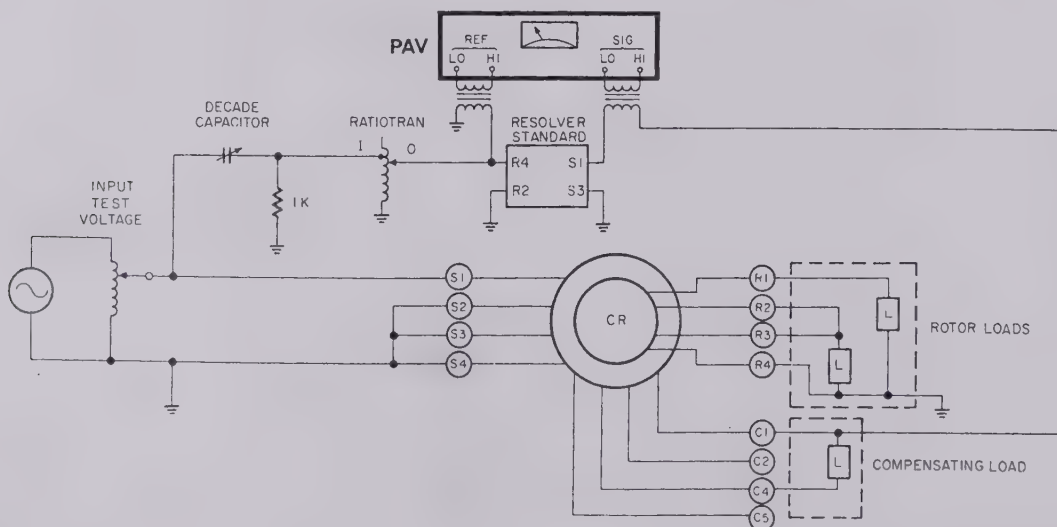


Figure A-3. Functional Accuracy Test

In this application, the PAV measures absolute amplitude at a selected frequency and phase angle (instead of detecting nulls). For point-by-point frequency response measurements, a variable frequency module is required. The RatioTran provides very precise changes in input level.

A-18. A specific frequency and amplitude level are used to establish nominal gain and phase shift through the device under test. Phase shift may be measured as outlined in paragraph 3-1 and gain may be measured in the phase sensitive or fundamental modes. The nominal gain may then be set for full scale indication as outlined in paragraph 3-3. Subsequent indications may then be read as a direct percentage figure.

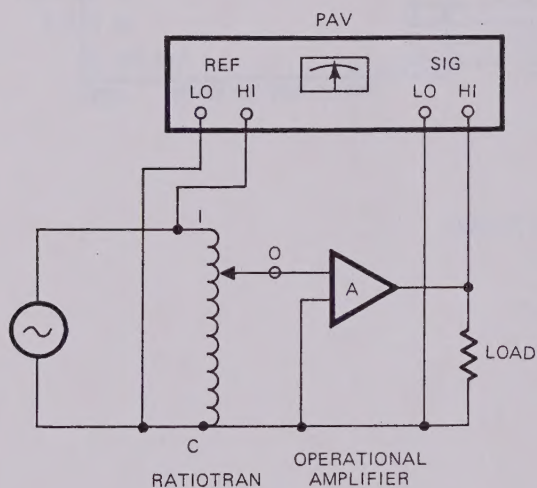


Figure A-4. Operational Amplifier Test

A-19. This same technique may be used for transformer tests (figure A-5), filter analysis, transducer tests (figure A-6), etc.

A-20. SERVO SYSTEM TESTING.

A-21. One important test of a system is to measure the exact output angle of a synchro or resolver installed in that system. In the Gertsch method, the system is set to the required position and a decade bridge and null indicator are used to measure the angle. The decade bridge is adjusted to obtain an exact null on the null indicator and the exact angular position of the synchro or resolver may be read from the dials of the bridge; The PAV may also be used to measure the approximate phase shift angle of the system.

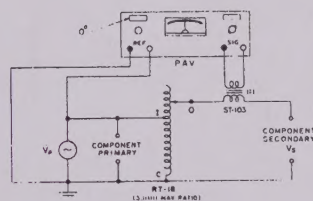


Figure A-5. Transformation Ratio Test

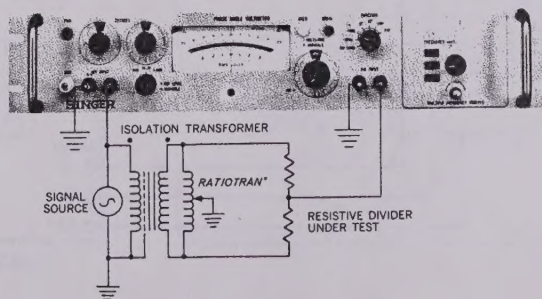


Figure A-6. Transducer Tests

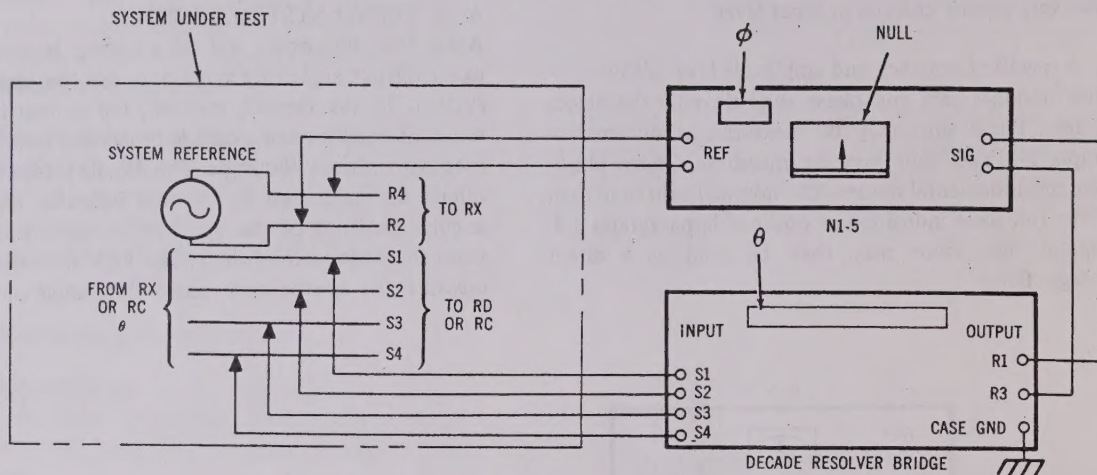


Figure A-7. Resolver System

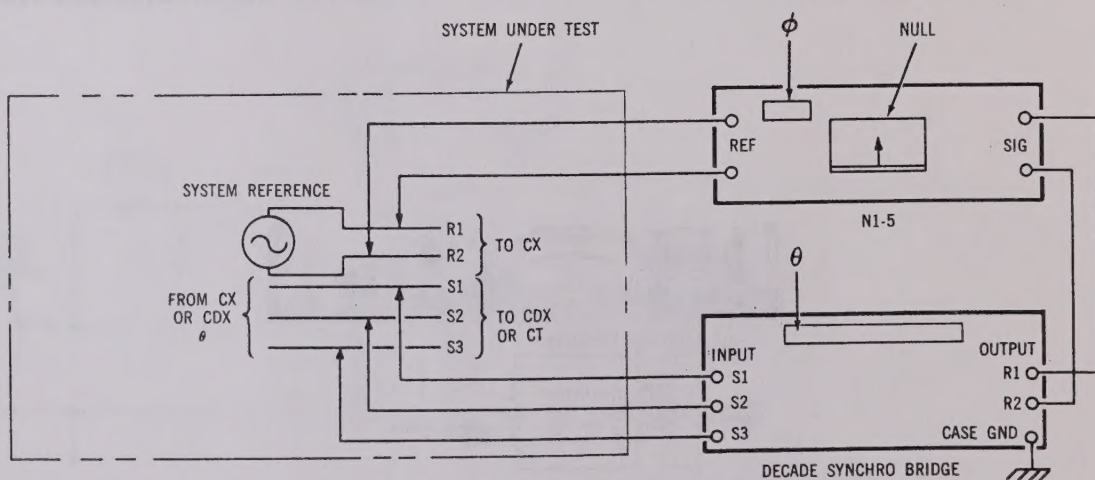


Figure A-8. Synchro System

